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1934.

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APPENDICES.

Proceedings of the inaugural meeting of the Indian Roads Congress held at New Delhi on the 10th to 13th December 1934.

The Indian Roads Congress met at the Town Hall, New Delhi, at Eleven of the Clock, on Monday the 10th December 1934. The following delegates were present:—

PROVINCES.

Madras.

Mr. A. Vipan, Special Engineer for Road Development, Madras.

Mr. D. Daniel, District Board Engineer, Tinnevelly.

Bombay.

Mr. L. E. Greening, Deputy Secretary, P. W. D., Bombay.

Mr. N. V. Modak, City Engineer, Bombay Corporation.

Bengal.

Mr. D. J. Blomfield, Chief Engineer, P. W. D., Calcutta

Mr. V. A. Stein, Superintending Engineer, Calcutta.

Mr. Pramatha Nath De, District Board Engineer, Burdwan.

United Provinces.

Mr. C. F. Hunter, Superintending Engineer, Lucknow.

Mr. S. S. Bhagat, Executive Engineer, Meerut.

Mr. A. Eastmond, M.C., Executive Engineer, Agra.

Punjab.

Mr. D. Macfarlane, Chief Engineer and Secretary to Government, P. W. D., Lahore.

Mr. S. G. Stubbs, O.B.E., Superintending Engineer, Ambala.

Mr. S. Bashiram, Executive Engineer, Ambala.

Mr. G. W. D. Breadon, District Board Engineer, Gurdaspur.

Burma.

Mr. O. H. Teulon, Chief Engineer, P. W. D., Rangoon.

Mr. H. Hughes, Superintending Engineer, Rangoon.

Bihar and Orissa.

Mr. J. G. Powell, Chief Engineer, P. W. D., Patna.
Mr. N. G. Dunbar, Deputy Chief Engineer, Patna.
Captain G. F. Hall, M.C., Superintending Engineer, Muzaffarpur.

Central Provinces.

Mr. H. A. Hyde, M.C., Chief Engineer, and Secretary to Government, P. W. D., Nagpur.
Rai Bahadur Sunderlal, Superintending Engineer, Nagpur.
Mr. P. V. Chance, Superintending Engineer, Raipur.

Assam.

Mr. B. F. Taylor, V.D.; Offg. Chief Engineer, Shillong.
Mr. G. Reid Shaw, Superintending Engineer, Shillong.
Mr. K. E. L. Pennell, Assistant Chief Engineer, Shillong.

North-West Frontier Province.

Mr. G. A. M. Brown, O.B.E., Superintending Engineer, D. I. Khan.

Delhi.

Mr. S. N. Chakravarty, Municipal Engineer.

Central P. W. D.

Mr. A. Brebner, C.I.E., Chief Engineer.
Mr. F. T. Jones, C.I.E., M.V.O., Superintending Engineer.
Mr. A. Croad, Superintending Engineer.
Sardar Bahadur Sardar T. S. Malik, C.I.E., Superintending Engineer.
Mr. A. W. H. Dean, M.C., Executive Engineer.
Khan Bahadur M. Z. A. Faruqi, Executive Engineer.
Sardar Uttam Singh, Executive Engineer.
Mr. M. A. Abbassi, Assistant Engineer.

Military Engineer Services.

Major W. B. Whishaw, M.C., R.E., Army Headquarters, Simla.
Lt. Col. A. V. T. Wakely, D.S.O., M.C., C.R.E., Peshawar.
Lt. Col. E. L. Farley, M.C., R.E., C.R.E., Lucknow.
Captain W. B. Robertson, R.E., Garrison Engineer (Civil) Quetta.

INDIAN STATES.

Hyderabad.—Mr. H. M. Surati, Divisional Engineer, Roads.

Mysore.—Diwan Bahadur N. N. Ayyangar, Chief Engineer and Secretary to Government, P. W., Railway and Electrical Departments.

Gwalior.—Rai Bahadur S. N. Bhaduri, Chief Engineer, (P. W. D.).

Baroda.—Mr. V. R. Talvarkar, Ag. Chief Engineer.

Travancore.—Mr. G. B. E. Truscott, Chief Engineer.

Patiala.—Rai Bahadur A. P. Varma, Chief Engineer.

Jodhpur.—Mr. S. G. Edgar, Superintending Engineer.

Jaipur.—Mr. P. L. Bowers, C.I.E., M.C., State Engineer.

Indore.—Mr. G. P. Bhandarkar, Chief Engineer.

Bhavnagar.—Mr. Ghooghari, State Engineer.

Kolhapur.—Mr. D. G. Sowani, Executive Engineer.

Patna (Orissa State).—Mr. D. V. W. Ottley, Chief Engineer

Kashmir.—Mr. Kishen Chand, Chief Engineer.

BUSINESS REPRESENTATIVES.

Mr. G. L. W. Moss, Dunlop Rubber Company, Bombay.

The Honourable Mr. E. Miller, J.P., President, The Indian Roads and Transport Development Association.

Mr. E. O. Austin, Ford Motor Company, Bombay.

Mr. W. B. Gunnell, Chief Engineer, Ford & Macdonald, Ltd., Cawnpore.

Mr. J. M. Fetters, William Jacks and Co., Bombay.

Mr. C. D. N. Meares, Standard Vacuum Oil Co., Calcutta.

Mr. G. G. C. Adami, Burmah Shell Company, Calcutta,

Mr. H. E. Ormerod, Vice-President, The Indian Roads and Transport Development Association.

Lt.-Col. H. C. Smith, O.B.E., M.C., M.L.C., General Secretary, The Indian Roads and Transport Development Association.

Mr. W. J. Turnbull, the Concrete Association, Bombay.

Mr. T. C. Marschalko, Texas Company, Bombay.

Mr. W. H. Kerr, Shaw Wallace and Co., Bombay.

Colonel G. E. Sopwith, Turner Morrison and Co., Calcutta.

Mr. Nurmahomed M. Chinoy, The Bombay Garage, Bombay.

Mr. A. S. de Mello, Gwalior and Northern India Transport Company, New Delhi.

Mr. W. H. Rowlands, Burmah Shell Company, New Delhi.

Mr. W. Brodie, Burmah Shell Company, Karachi.

Mr. R. W. Parkhurst, A.M.I.E., (Aust.), Trinidad Lake Asphalt Operating Company, Sydney, N.S.W., Australia.

Rai Sahib L. Hari Chand, The Concrete Association, Lahore.

GOVERNMENT OF INDIA.

Mr. K. G. Mitchell, C.I.E., Consulting Engineer (Roads).

Mr. R. G. Burt, Assistant Director, Inspection, Indian Stores Department.

The Honourable Sir Frank Noyce, K.C.S.I., C.B.E., I.C.S., Member for Industries and Labour, in opening the proceedings spoke as follows:—

Gentlemen,

I have very great pleasure in welcoming you on behalf of the Government of India and in wishing all success to your meeting. I trust that none of you is any the worse for the strenuous tour Mr. Mitchell, who never spares himself and, I imagine, is equally unsparing of others, arranged for you last week and that you found it both interesting and instructive.

This, I feel, is an occasion the significance of which is worth emphasising as it may well mark the beginning of an organisation of real value which should exercise a great influence on the development of road communications in India, not only in regard to their quality but also in regard to their cost. I should like, at the outset, to emphasise the purely professional and scientific character of the agenda which has been placed before you. You are not concerned with that very difficult problem, competition between road and rail transport; with the question to what extent development of our road systems from loan funds is desirable; with economic planning and the like. Those are questions which will come up for consideration next month by the Transport Advisory Council which, like your Congress, will then be meeting for the first time. You as Engineers are concerned with technical rather than administrative questions and incidentally with the desirability of forming yourselves into a continuing organisation for discussing them. I have thought it desirable to lay some stress on this point as I feel that there has been some misunderstanding about the precise scope and aims of this Congress which it is advisable to remove.

We have been distinctly embarrassed by the wealth of applications to attend this meeting. We could not possibly invite all those who desired to come. All we could do was to arrange to the best of our judgment for a reasonably representative meeting which could itself draw up proposals for the composition and organisation of future gatherings of this character. I think we can claim that we have succeeded in our object.

There are here to-day Chief Engineers and public works officers from every province and a number of States; officers of the Military Engineering Services; Municipal and District Board Engineers; and last, but by no means least in importance, for I regard non-official co-operation in this matter as essential, representatives of the business side of road construction and road transport. I cannot but think that your verdict regarding the value of a permanent organisation and the shape it should assume will be unhesitatingly accepted as authoritative.

It is hardly necessary to remind a gathering such as this that, since the dawn of history, roads have been of the first importance to civilisation and indeed a measure of its progress. Our archæologists are piling up more and more evidence of the truth of that statement. At Harappa in the Punjab, they have found a model in copper of a two wheeled cart very similar to the bullock cart of the present day. What was good enough for the Indian ryot four thousand years ago he still thinks good enough to-day. Inscriptions discovered at Babylon show that 2,500 years ago both Nebuchadnezzar and his father built roads "of shining dust

made strong with bitumen and burnt bricks as a high lying road"—a type of construction recently revived in the Punjab and elsewhere in India.

I should be more or less than human if I refrained from mentioning the Roman Road. The Romans were empire builders in a different way than they realised and I hold it not too materialistic an interpretation of their achievement to say that all their gifts and bonds of law, language, literature, or administration would have been either impossible or impermanent had they not been bound together by their system of roads. You know the Roman symbol which has been given so widespread and impressive a restoration of late years—the rods and axes. The rods are bound together and anything that is to last must have some binding. A system of communications plays that part. As Hilaire Belloc puts it "It is the road which is the channel of all trade and, what is more important, of all ideas. In its most humble function it is a necessary guide without which progress from place to place would be a ceaseless experiment: it is a sustenance without which organised society would be impossible; thus, and with those other characters I have mentioned, the road moves and controls all history".

The invention about a hundred years ago of a specialised form of road, the rail-road, divested the public highway for the time being of much of its importance But, a later invention, that of the internal combustion engine caused the pendulum to swing back again. Roads have resumed their place in the economic system and the commerce and industry that the railways have made possible have enormously increased the complementary uses to which they can now be put. There has in consequence been a great revival of interest in them, a revival which has brought into existence a whole sheaf of new problems. That brings me to some consideration of the character of these problems and the position of the Government of India in regard to them.

Roads, as you all know, are a provincial transferred subject but I think I may say that it was the realisation of their national importance which led to a Resolution in both Houses of the Indian Legislature in February 1927, as a result of which the Indian Road Development Committee (the Jayakar Committee) was appointed. That Committee reported in 1928 and their report has been the basis of all that we in the Government of India have since been able to do in this field. I am sure that most, if not all, of you have read it and that you will remember that, after stating the reasons why the road system of India ought to be developed, the Committee suggested that the task was passing beyond the capacity of local Governments and local bodies and was becoming a matter of national interest, expenditure on which might to some extent be a proper charge on Central revenues. They therefore recommended a surcharge of two annas per gallon on petrol, and it is from this that the present Road Account derives its sustenance. It is in accordance with some of their other recommendations that part of the account has been placed at the disposal of the Government of India—on the advice of a Standing Committee of the Central Legislature—and that from this reserve provision is made for research and experiment. It is of special interest to us to-day to note that they advocated periodical road conferences to discuss, amongst other things, technical questions relating to road construction and maintenance

I should like, in passing, to offer a tribute to the remarkable comprehension and foresight displayed in the report of this Committee which laid well and truly the foundations of all that the Government of India have been able to do in recent years to assist the provinces to develop their road communications.

In following their recommendations we were handicapped to some extent by the fact that the arrangements they suggested were introduced in the first instance for five years only. During that time we thought it best to confine ourselves to immediate problems and to avoid elaborating a structure which might shortly have to be dismantled. We made certain grants from time to time for various experiments; in the magazine "Indian Roads" we endeavoured to provide a medium for the distribution of useful technical information; and when the Road Conference of 1931 met, we arranged for technical committees to discuss certain matters. Our activities were also to some extent hampered by pre-occupations arising out of the enquiry into competition between road and rail transport and the conference of 1933 which met to discuss its results. We were fully and uneasily aware that we were not wholly keeping pace with the requirements of the situation but we preferred to wait until we could plan our work with some hope of permanence. The Resolution adopted by the Central Legislature in April last providing for the continuation of the Road Account without any specified period of time has naturally altered our outlook. One of the first things we did after it was passed was to consult Local Governments in regard to the convening of this Congress.

A layman never finds himself in a more difficult position than when he has to talk to a meeting of experts and I trust you will need no assurance from me that it is with becoming diffidence that I advance a few suggestions as to ways in which the science of road building in India might be advanced. When experiments have to be carried out on ordinary roads, particularly in the use of the more durable materials, it takes a long time to secure data of real value. On the other hand, a test track should enable such data to be forthcoming in a comparatively short time. Is it desirable that such a track should be provided possible as part of a complete experimental station with laboratory equipment? In other countries, much laboratory research work has been done on the physical and chemical properties of various road making materials upon which are based certain standard specifications. Do we need similar research and specifications specially adapted to our varying conditions of climate? The scientific study of soils in their relation to earth roads and road foundations has up to the present been almost wholly neglected in India. Should this be promoted by research scholarships and in other ways? Is it desirable that more should be done in the way of sending our young Engineers to study the science of road making in other countries? It seems to me that it is only by giving this Congress a permanent standing that we can ensure not only scientific discussion and the pooling of knowledge but also the expression of informed opinion on matters such as these, and that an Indian Roads Congress by its annual meetings and the deliberations of special committees could be of immense value in directing research and research policy and in standardising specifications and practice.

There may be some who think that, with the impending change in the Constitution and the advent of provincial autonomy, there will be no need for conferences such as this. That is a view which I have always

strongly resisted. Provincial autonomy does not and should not mean provincial isolation with all its attendant evils of duplicated experiment and waste of effort. In the India of the future as I see it, there will be an even greater need than there is to-day for common meeting ground for Provinces and States. I feel most strongly that every link that can be forged between them now will prove its binding value in the years to come. It is my hope that you will to-day forge another link to add to these which already exist—such bodies as the Imperial Council of Agricultural Research and one which will shortly begin to function, the Advisory Council attached to the new Bureau of Industrial Intelligence and Research. The United States of America, a federal country in which the States are very jealous of their rights has set the Federal India of we hope, the near future an example in this respect in its Highway Research Board.

That brings me more specifically to the question of your future organization. You will be invited this morning to consider and express your opinion on two main questions in regard to it. Firstly do you consider that any permanent organisation to promote meetings of this sort is necessary? and, secondly, if you do, what, in general terms, should be the nature of that organisation? I must say quite plainly that the paper on this subject which has been placed before you does not represent the opinion of the Government of India. It has not even been considered by them. It purports to put certain considerations and some sketch proposals before you and it invites you to express your views in general terms and to nominate a committe to make definite proposals for your consideration. If you decide that a permanent organisation is required, you will not expect me to say more than that I think the probabilities are that we should agree with you. If your proposals appear to us to be sound and reasonable, as I have every hope they will be, we shall consider, in consultation with Local Governments, whether we cannot assist you. We are provisionally of the opinion that your organisation should be largely self-contained and it is for that reason that we have left it to you to make your own suggestions. I realise that, in the busy days before you, it may not be possible for you to complete your proposals. If that is the case, you will doubtless arrange for a further meeting of your committee, or of a sub-committee.

Time does not permit me to do more than say a very few words about the other items on your agenda. The papers presented to you for discussion and the note* describing roads round Delhi which you will have an opportunity of seeing to-morrow cover a wide range of subjects and represent much solid work, and I am sure that you would wish me on your behalf to thank all those who have taken the time and trouble to prepare them and to place the results of their experience and knowledge at your disposal. You will doubtless have noticed that certain of them were not written for this meeting but for the last International Roads Congress, and our thanks are due to the authors for allowing us to make use of them here, where they will be of special interest. I understand that that Congress was the first to which papers were contributed from India. I regard that as a matter for congratulation and I think we may now confidently look forward to the day when papers from India will be regular and valued feature of those Congresses.

As one whose good fortune it has been to be brought into special touch with the conditions of rural India, I am glad to notice two papers

*Paper No. 1-A.

dealing with earth roads by experts whose keeness, interest and extensive experience entitle them to speak with authority on this most difficult subject. I will not take up your time with figures for I am sure you all know how great a proportion of our road milage is and must remain unmetalled. Individually earth roads may not carry much traffic but collectively I would remind you that they carry the whole of the agricultural produce of the country before it reaches a metalled road—which much of it never does—on its way to a market. The keen competition between the primary producers in world markets at the present day has brought home to us the importance of eliminating all avoidable waste incidental to marketing. Steps are being taken to organise and improve the business technique of marketing, but the improvement of transport facilities rests with you. There are other reasons why the improvement of unmetalled roads is of the first importance. Much of the expense of maintaining metalled roads is due to the combination of fast motor traffic with destructive bullock carts. There are some who hold that the key to the Indian road problem lies in the improvement of the bullock cart. That is doubtless true to some extent but development cannot wait for it. In any case, it seems to me that no great change in the bullock cart can be expected so long as the earth roads provided for it remain as bad as they are. Again, the possibilities of motor transport to serve the rural population are immense but can never be fully developed so long as it cannot reach important villages, and is confined to metalled roads at some distance from them.

The remainder of your Papers deal with hard surfaced roads in one aspect or another. This is natural because the bulk of the road bill is made up of the cost of maintaining them. If you can economise here so much more money will be available for expansion and, what is perhaps more important, the fear of increasing maintenance bills will not be such a deterrent, as it now is, to a liberal policy of expansion.

You will perhaps forgive me if I say that I could have wished that some one of your number had forsaken the strictly utilitarian and had given you a disquisition on the æsthetic and scenic aspect of roads. There is something very attractive about a road, despite the fact that when one is stranded miles from anywhere on a hot afternoon after a series of punctures, the stretch of road between car and destination offers perhaps one of the most horrible prospects ever offered to the human eye. I admit that it would be difficult in such tracts as the Ramnad district in Madras and parts of the Punjab and Sind to do anything with a road except to be glad that it is there but in most other parts, especially in the hill tracts, there is much scope for making the road a scenic as well as a practical feature. Even in such technical matters as width, curve and camber, there may reside potentialities of grace and elegance as great as in more obvious features such as avenues. To me there is a marked and immediate æsthetic connexion between the width of a road and the height of the buildings that run along it. The artistic possibilities of bridges must be apparent to all. Modern life brings its own problems and one of them is apt to be the cramping of imagination, the cult of the stodgily useful. I would therefore make a humble plea for beauty wedded to utility. The union is not fantastic, for the highest usefulness is almost inevitably beautiful. Did not Ruskin, that apostle of the beautiful, employ his students on making roads?

You with your great experience will, I am sure, agree that the conditions of road making and road maintenance in India are exceptionally difficult. Long draughts are succeeded by torrential rain. The bullock cart with the heavy load it imposes on the road surface and its propensity to "track" presents its own peculiar problem which has few, if any, parallels elsewhere. India is a poor country and the resources at its disposal fall far short of its needs. The Minister of Transport in England is reported to have said recently "We desire that the road of the future shall be the most modern that engineering skill and traffic experience can devise". Our desires must, I am afraid, be more modest, and we can only ask you to give India the greatest milage of serviceable road that the money at your disposal permits Every additional mile of good road is an asset to all; every mile of bad road an economic loss to all and the cause of discomfort to many Your difficulties are great, but I am quite sure that the word "insuperable" has never yet been found in any Engineer's vocabulary.

I have kept you long enough. In conclusion, I would remind you that the communications of a country may be likened to its nervous system. A country with poor communications is bound to remain inert. You will probably say that the obvious deduction from this is that overdevelopment of communications must produce some form of cerebral frenzy where people run about for the sake of running about. That is, in fact, the stage which some harsh critics maintain has already been reached in Western Europe and the United States India is, however, far from it and indeed the development of India's communications has a close bearing on the political problems with which she is faced to-day. Unless the social communications of the country can keep pace with its political development, it is highly probable that the unity on which such store is rightly set may be endangered or at least hindered And thus we see that in the great political changes on the threshold of which we stand, the proper treatment of communications occupies an important place, indeed if the word is given its widest connotation, perhaps *the* most important place. I will now leave you to your deliberations and would once again wish them all success. [Applause.]

The Congress adjourned for a group photograph and then reassembled, with the Honourable Mr. D G. Mitchell C.S.I., C.I.E., I.C.S., Secretary to the Government of India in the Department of Industries and Labour, Public Works Branch, in the Chair.

A hearty vote of thanks was first passed to the Chief Commissioner of Railways and the North Western Railway for the special arrangements made to provide a suitable train for the tour of the Indian Roads Congress.

[An account of the tour of inspection of roads in the Punjab and the North West Frontier Province which preceded the Congress appears as Appendix A to these proceedings.]

Chairman: I will now call upon Mr. K. G. Mitchell to introduce his paper on the objects and organisation of a permanent Indian Roads Congress.

The following paper was then submitted for discussion:—

(*Paper No. 1.*)

Objects and Organisation of a Permanent Indian Roads Congress.

By K. G. Mitchell, C.I.E., M. Inst. C. E.

This first meeting is experimental. The Government of India are so far satisfied as to the potentialities of such a body as to defray practically the whole cost. Without their generous support it would have been difficult if not impossible to have this meeting, but if any permanent body is to come into existence this opportunity must be taken to draw up a constitution and to estimate the extent of the financial support from the Central and Local Governments that will be necessary, in order that a scheme may be submitted for their approval. It is proposed that on the first day of the Congress a committee be appointed to make recommendations for adoption or amendment by the whole Congress on the last day. That committee will thus have very little time in which to consider the whole question and the object of this Paper is to provide a basis for its discussions. If those attending the Congress will criticise these proposals freely on the first day, the work of the committee will be greatly simplified. This committee might be the General Committee of the Congress as proposed below.

2. *Necessity for some such organisation.*—There is little to add to what has already been said on this, both in the original suggestion to Chief Engineers and in the printed pamphlet* incorporating concrete proposals for this meeting. It will be enough to add that the present age is one of rapid change in which few of us have leisure to keep in touch with all the technical developments that affect us, and in which we require the services of some organisation to keep us up to date and enable us to see and hear at first hand how others are dealing with problems similar to ours. The mass of technical literature is so great that it is impossible to read it all, while no amount of reading can be so useful as personal inspection of work and first hand discussion with those who have done it.

3. There is an added need for such a body in the domain of roads in a federal or *quasi*-federal constitution. Standardisation of specifications for methods and materials of construction, of the loading for which bridges are to be designed, and in respect of a number of other matters are desirable for economy and convenience, even in a country of the size of India. Because of the constitutional position and because these are largely professional matters, there is no official authority to specify standards. Standard specifications and practice approved by a body such as the Indian Roads Congress, as representing the considered opinion of the Road Engineering profession, would be sufficiently authoritative to be widely adopted without in any way invading the autonomy of the federal units.

4. There are other problems of great professional interest the solution of which lies in other hands, but in respect of which the opinion of such a body as this would carry great weight. An illustration which will occur to every one is the problem of the bullock cart. We have now got to make dual purpose roads with inadequate funds in a country which persists, in the view of some of us, in permitting abuse of the roads by wholly uncontrolled and extremely

*Not reproduced here.

damaging bullock cart traffic. It is fantastic to suppose that the bullock cart will disappear within any period of time likely to affect us or many generations to come, but it ought to be possible gradually to educate people and Governments to understand what *laissez faire* is costing them in money and arrested development, and so to bring about the gradual introduction of reasonable regulations. Individually our voices will remain unheeded. The opinion of a body such as we contemplate would carry very great weight. Again, it is fortunate that so far the development of motor transport has not required, outside the towns, vehicles heavier than the 30 cwt. class, and roads are being adjusted to carry these; but technical developments, such as the improvement of the compression-ignition engine, might result in the use of far heavier vehicles beyond the capacity of the type of road now being developed. In such an event and in respect of speeds to be permitted for various vehicles on different types of road, and on other matters such as the compulsory provision of "governors", the voice of the Roads Congress would be listened to while that of individuals might not.

5. The Congress might at times also discuss with advantage such questions as the administration and organisation of a roads department or office and such other matters as may generally be defined as business management. It should quite definitely not discuss or attempt to interfere in personal matters connected with the conditions of service of any individual member or group of members. There should not be any doubt on this point but it is as well perhaps to state it quite definitely at the outset.

6. *Objects.*—The objects of the Congress might therefore be stated thus :—

> To provide for a regular pooling of experience and exchange of ideas on all matters affecting the construction and maintenance of roads in India: to recommend standard specifications: and to provide for the expression of the opinion of the Road Engineering Profession on matters affecting their work, including organisation and administration but expressly excluding personal matters or questions concerning conditions of services.

7. *Membership.*—Subject to the specific or general approval of the General Committee, membership might be open to all professionally qualified Engineers engaged or concerned in the construction and maintenance of roads, whether in public employ or not. The standard of professional qualification necessary might be not less than that required for direct recruitment to the rank of Assistant Engineer in a Provincial Service. Anyone holding that or, in the opinion of the General Committee, equivalent rank though not qualified by professional examination, might also be eligible. It was at one time contemplated that for large firms such as those dealing in road making materials, there might be a class of corporate membership, but individual membership will probably be the better arrangement. It would however be desirable to include non-professional gentlemen closely concerned or interested in roads, as associates. Also in order to grade subscriptions to some extent there should be two classes of members, *i.e.*, members and associate members. Election or transfer to full membership would be made by the General Committee and would normally be confined to persons of the equivalent rank of Executive Engineer or over. It is not the intention that by

grading membership in this way the Congress should set itself up as a body imparting a certain professional status, but it appears to be desirable to grade subscriptions and this can better be done in this way than by an attempt to relate them to emoluments. The latter arrangement might give rise to difficulties in the case of those not in the public service.

8. *Subscriptions.*—It is necessary to have some subscription to cover part of the expenses, and for other obvious reasons. The rates suggested are :—

	Rs.	
Members	10	per annum.
Associate Members	5	per annum.
Associates	20	per annum.

A fairly high rate is desirable in the case of associates to restrict applications to those having a genuine interest.

9. *Benefits to members.*—All members, associate members and associates would be on an equal footing as regards attending and speaking at meetings (subject to the arrangement regarding travelling allowance discussed below) and would receive the printed proceedings of the annual congresses and such other literature as might be circulated. It must be recognised that, for the majority, the benefit would be confined to the receipt of proceedings, and other literature, except those in whose Province the annual Congress is held who would, it is hoped, be able to attend in large numbers.

10. *Management.*—The management would be in the hands of a General Committee and Provincial Committees. Eventually some other arrangement may be possible, but for the present it is suggested that these committees be constituted as follows :—

(*a*) *General Committee.*—The Chief Engineers of Governors' Provinces and of the Central Public Works Department: the Consulting Engineer to the Government of India (Roads) ; two representatives of States elected by the delegates from States present at each annual meeting and three representatives of non-official associate members and associates, elected by such non-officials present at each annual meeting.

(*b*) *Provincial Committees.*—To be presided over by the Chief Engineer of the Province concerned and to consist of four officials (including the Chief Engineer) and one or two non-officials, all to be nominated by the Chief Engineer.

11. The General Committee will normally meet once a year at the time of the annual congress. During the year business will be carried on as far as possible by correspondence. The Consulting Engineer to the Government of India would for the present be responsible for the clerical work of the General Committee. All the funds and property of the congress would vest in the General Committee.

12. Subject to the financial control of the General Committee, Provincial Committees would be responsible for all the arrangements for the annual congress when held in their Province, including the selection of Papers and

the arrangements for visits to works. They would arrange for someone to act as Secretary. The General Committee would have power to give general directions to Provincial Committees and to overrule them, *e.g.*, in the matter of selection of Papers.

13. *Finance.*—Until the numbers likely to join the Congress are known it is impossible to gauge the probable income. It is believed however that the rates of subscription proposed should suffice to cover the cost of reporters, printing and postage. If the proposals eventually made commend themselves to the Central and local Governments some support may be expected, and this might be asked for, by way of an initial lump sum grant from the Government of India and, in addition, some assistance with travelling allowances.

14. *Travelling allowances.*—The Government of India, having agreed to defray the whole cost of this meeting, feel that the justification for the creation of a permanent body will lie in the benefits which local Governments derive therefrom in the application of the results to their own road systems, and that this justification can best be gauged by the willingness of local Governments to bear the expenses of delegates in future years. The Papers read and discussed will, or should, be of general interest, while the attendance of delegates will be largely in the interest of their Province. An equitable arrangement would perhaps be that the Congress should defray the expenses of the contributors of selected papers and that local Governments should meet the expenses of other delegates In the case of tours or visits in connection with any annual congress, travelling allowance would be paid under the usual rules and the Congress would not normally be called upon to meet any expense in respect of ordinary delegates attending those. The lump sum grant from the Government of India suggested above would enable the Congress to pay the expenses of contributors of papers, and it is for this reason that the general committee should have power to overrule any Provincial Committee in the selection of papers.

15. It is to be hoped that local Governments will agree to send a reasonable number of delegates to distant meetings, and in the case of the Province in which the meeting is held, to allow travelling allowances to all members and associate members in the Province able to attend the meeting.

16. *Annual Congresses.*—The Congress should meet once a year, and at a different centre each year. It will be necessary for an invitation to be given by a local Government before the Congress can decide where to meet. It will be convenient if such invitations can be given for the following year at or before any annual meeting. In the event of more than one invitation being received the Congress will decide. Will Chief Engineers please note that an invitation is necessary for the 1935 Congress? It will necessarily be provisional only and dependent on the Central and local Governments, and particularly the local Government concerned, approving the permanent creation of the Congress.

17. *Name.*—The name "Indian Roads Congress" has been used in the preliminary correspondence. It is open to anyone to propose a better. The use of the word "association" is rather barred by the existence already of the Indian Roads and Transport Development Association.

18. *Proceedings at Meetings.*—A member of the General Committee will preside at each session. Normally papers on professional matters, circulated in advance, will, as is the usual custom in professional bodies, be merely introduced by the author and thrown open for discussion. The discussion will be reported and printed up in the proceedings. Cases may arise however where it is desirable that the Congress should register an opinion in the form of a resolution. At the first meeting it is unlikely that the Congress will desire to do so save in respect of the matters discussed in this paper. A draft resolution will be submitted by the Committee on this question with its report.

19. *Miscellaneous.*—Once established, the Congress can do a number of things. A gold medal might be given for the best Paper each year. Committees could be set up to advise on standardisations, education in Road Engineering, research or study scholarships in India or overseas, and so forth.

20. *Conclusion.*—It is believed that the value of some permanent organisation will not be questioned. The difficulties are obvious. The proposals made in this Paper are designed to provide a working arrangement to tide over the earlier years. They are manifestly imperfect in many respects, but it can only be hoped that if they are subjected to searching criticism before the committee gets down to work, something better will result. It only remains to add that the views and suggestions thrown out in this Paper are those of the writer and in no sense those of the Government of India who await your proposals.

Mr. K. G. Mitchell (the Author): As regards this paper, it is merely a series of suggestions thrown out as a basis for discussion. There are only three main questions and I think it would be advisable if those who have anything to say would confine themselves to the three questions that I am going to raise. The first is:—Is it desirable to have such a body? secondly, how it should be constituted, and thirdly, how it should be financed. I have nothing to say on No. 1 and I would like you to say whether such a thing is necessary or not. As regards No. 2, the only possibility seems to be to have a self-contained body organised on a non-official basis. You can take it from me that it is impossible to have an official body, if we want to make it representative. It is practically impossible for anybody at headquarters to pick and choose who shall come. We did suggest to Local Governments that they might indicate how the business representatives should be chosen. They found the same difficulty and the only solution, if it is going to be at all representative is to have a regular membership, with a nominal subscription. Otherwise it will be impossible for the Government of India to say who shall come and who shall not. I think also that some subscription is necessary. As regards finance, it is obvious that in a country of the size of India where the cost of travelling is so great some Government support is essential. On that point, I wish to say one thing. The Roads Congress should be your show and not a Government show. If you say that the whole support should come from Government, then you rather prejudice your own management of your own affairs. Now, in this paper it is suggested that there should be a committee elected this morning to consider the whole question and to make a report probably on Friday morning. There is no need to elect a Committee as regards British India. It will consist of the Chief Engineer or senior representative of any province present or his nominee. As regards the States, I say in the paper that we might have two representatives on the permanent committee. Owing to the number of States represented at this meeting to-day, it is better perhaps to make it 3. We will ask the State representatives some time during the morning to nominate three of their members to join this committee. Similarly, the business representatives will kindly nominate three of their number to serve on this committee. The committee will meet at 6 o'clock for a preliminary discussion, either in New Delhi at the Imperial Delhi Gymkhana Club or in Old Delhi in Maiden's Hotel according to where the majority of the committee are staying. After the conclusion of this morning's business, the committee will meet for a few minutes and decide where to have the meeting.

DISCUSSION.

Chairman: Has any gentleman any remarks to make on Mr. Mitchell's paper?

(Nobody arose.)

Chairman: I understand then that the general proposals as set out in Mr. Mitchell's paper are approved in broad outline. All that remains now is to ask for your approval to his suggestion that the committee should be constituted as indicated by him. Has any gentleman any remarks to make?

Mr. A. Brebner: Would it include Royal Engineers such as Colonel Wakely?

Chairman: I understand that Colonel Wakely is a Military Engineer attached to a province. He would be suitable to represent the N.-W. F. P. It has been suggested that two representatives of the Military Engineering Service should also be included in the committee.

Rai Bahadur S. N. Bhaduri: As regards the States, as the number of States is nearly 12 or 13, three representatives are not sufficient.

Chairman: I would point out that the committee will now consist of 9 representatives from provinces, 3 from States, 3 from the business community and 2 from the Royal Engineers. That makes 17. It is already getting to the limits of a working committee. But if there is any strong feeling in favour of a stronger representation from the States, perhaps some gentleman will indicate that.

Mr. P. N. De: There is no representative from the District Boards or municipalities. I think it would be better to have one from those bodies.

Lt.-Col. E. L. Farley: As regards the Royal Engineers, one would probably be enough, because we deal with specialised problems in peace time and that would give one to such other bodies as might wish to have it.

Chairman: Might I suggest that the present constitution gives us a sufficiently large body and that anything larger than that might make it unwieldy?

Mr. G. Reid Shaw: Representation for the District Boards is rather unnecessary. It seems unnecessary to have a representative of one District Board for the whole of India.

Chairman: Is it your suggestion that District Boards and municipalities should be excluded?

Mr. G. Reid Shaw: Yes.

Mr. V. R. Talvarkar: I propose that the Bombay municipality should have a representative. It has got a large area of roads and very important roads.

Chairman: I would suggest to you that if we start selecting individual municipalities, there will be no end to it.

By a show of hands, it was decided that there should be no representative of District Boards and municipalities.

Chairman: The feeling of the meeting is that this committee should consist of one representative from each province, three representatives from the Indian States, three from the business community and one from the Royal Engineers.

The Chairman then called upon the States and business representatives to elect three representatives each.

Mr. H. E. Ormerod: The Indian Roads and Transport Development Association have a Resolution to be put to the meeting in connection with the financing of the Congress.

Chairman: I think we had better finish this item first. We shall now proceed with the selection of the provincial representatives.

The elections were then held after which the Chairman announced the names of the Committee as follows:—

PROVINCES.

Madras.—Mr. A. Vipan, Special Engineer for Road Development, Madras.

Bombay.—Mr. L. E. Greening, Deputy Secretary, P. W. D., Bombay.

Bengal.—Mr. D. J. Blomfield, Chief Engineer, P. W. D., Calcutta.

United Provinces.—Mr. C. F. Hunter, Superintending Engineer, Lucknow.

Punjab.—Mr. S. G. Stubbs, O.B.E., Superintending Engineer, Ambala.

Burma.—Mr. O. H. Teulon, Chief Engineer, Rangoon.

Bihar and Orissa.—Mr. N. G. Dunbar, Deputy Chief Engineer, Patna.

Central Provinces.—Mr. H. A. Hyde, M.C., Chief Engineer, P. W. D., Nagpur.

Assam.—Mr. B. F. Taylor, V.D., Offg. Chief Engineer, Shillong.

North-West Frontier Province.—Mr. G. A. M. Brown, O.B.E., Superintending Engineer, D. I. Khan.

Central Public Works Department.—Mr. A. Brebner, C.I.E., Chief Engineer, New Delhi.

INDIAN STATES.

Rai Bahadur A. P. Varma, Chief Engineer, Patiala.

Diwan Bahadur N. N. Ayyangar, Chief Engineer and Secretary to Government, P. W., Railway and Electrical Department, Mysore.

Mr. P. L. Bowers, C.I.E., M.C., State Engineer, Jaipur.

BUSINESS REPRESENTATIVES.

Mr. H. E. Ormerod, Vice-President, the Indian Roads and Transport Development Association, Bombay.

Colonel G. E. Sopwith, Turner Morrison and Co., Calcutta.

**Mr. G. G. C. Adami, Burmah Shell Company, Calcutta.*

ROYAL ENGINEERS.

Major W. B. Whishaw, M.C., R.E., Army Headquarters, Simla.

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*Mr. C. D. N. Meares of the Vacuum Oil Company, Calcutta will serve on the Committee vice Mr. Adami.

Chairman: This Committee will meet this evening at 6 o'clock at some place to be decided by them subsequently before they leave this morning. This is one part of the business on which we have to make a decision this morning. The rest of the time we may spend on a discussion of the broader aspects of the proposal and I will Mr. Ormerod to make his remarks which he intended to make to-day.

Mr. H. E. Ormerod: On behalf of the Indian Roads and Transport Development Association I wish to move the following Resolution:—

> "In view of the interest which has been shown in this, the first Indian Roads Congress and the importance of ensuring that its continuance should be maintained regularly each year, it is recommended that owing to the financial stringency existing in the Provinces, the method adopted this year of financing the cost of the conference from the 10 per cent. reserve of the Petrol Road tax, held by the Central Government, should be maintained, if possible, during the next few years."

Chairman: May I just point out a small point of order. If you wish to move this as a Resolution, then it would be better to move it after the Provisional Committee has met. They will then consider it and frame their own recommendation. For the present, the discussion should be confined to the giving out of the indications of the general feeling of the meeting.

Col. G. E. Sopwith: Mr. Chairman, I cannot second the Resolution after what you have said, but I should like to say this that I personally think that the suggestion is an extremely good one.

Mr. D. Macfarlane: I would like to add to what Mr. Ormerod and Col. Sopwith have said. I think that if something of this sort is not done, there will be a great difficulty on the part of the poorer provinces to finance the journeys of their officers with the result that people who are not supported by their Governments could not possibly afford to attend this Congress.

Chairman: As nobody else wishes to speak on this question, I would like to say that if you decide in favour of this particular financial arrangement, I would advise you strongly to have a second string to your bow. I am not able to commit the Government of India but they may or may not accept the suggestion and the whole arrangement might fall to the ground. So, it will be better to have an alternative arrangement.

Mr. B. F. Taylor: May I refer to sub-para. (*b*) of para. 10 of Mr. Mitchell's paper regarding Provincial Committees which are to be presided over by the Chief Engineer of the province concerned and to consist of four officials (including the Chief Engineer) and one or two non-officials, all to be nominated by the Chief Engineer. Are we to understand that these are to be left to be decided by the various provinces?

Chairman: I think that is a matter of detail and we had better leave it to the Committee. It is certainly a point worthy of their consideration.

Chairman: Mr. Dean will now make some remarks on his paper and after he has finished, the members of the Provisional Committee will remain behind and make their preliminary arrangements which would help in the despatch of the business.

Mr. A. Brebner, C.I.E., Chief Engineer, Central Public Works Department then took the Chair.

Chairman: Before I introduce Mr. Dean, I should like to propose a vote of thanks to the Hon'ble Mr. D. G. Mitchell.

The motion was received with applause.

Chairman: Mr. K. G. Mitchell has already explained to you the alterations in the programme which necessitate our starting on our tour this afternoon instead of to-morrow morning. On the whole, I think, probably the change is a good one because it will enable us to discuss Mr. Dean's paper after you have seen the work instead of before it. But in the meantime Mr. Dean would like to make a few remarks in introducing the paper and explaining what in particular he wishes to say. I introduce Mr. Dean. I may add that in accordance with the ordinary practice we propose to take the paper as read.

The following paper was then submitted for discussion

(*Paper No. 1-A.*)

Recent methods used for the treatment of roads with bitumen and tar in Delhi Province.

By A. W. H. Dean, M.C., I.S.E.,

Executive Engineer, Central Public Works Department.

Prior to the year 1925 the hard surfaced roads in the Province were all either metalled with kankar or quartzite stone ballast. Kankar being a soft material and unfit to carry heavy traffic its gradual replacement with the latter material was, however, the aim and by the close of the year 1931 all metalled roads in the Province had received a wearing coat of water bound stone metal. None of the roads in the Province were surfaced with tar or bitumen and this treatment was entirely omitted from the New Capital Project.

The earliest example of bituminous treatment was the length of road from Lothian Bridge to Delhi Gate which was carried out in September—October 1925. This length was divided into the following three sections according to the condition of the old surface in each:—

1. Surface recently remetalled.
2. Surface remetalled one year before.
3. Surface requiring remetalling.

All three sections were treated similarly. The surface of the road was very carefully broomed and cleaned of all dust and dirt before the application of the bitumen and the temperature of the bitumen was very carefully regulated. Trinidad refined asphalt mixed with Flux oil in the proportion of 60/40 was sprayed at the rate of 4·5 to 5 lbs. of the mixture per sq. yd. and was evenly covered with 3/8 inch stone grit and rolled.

The surface in the three sections was very satisfactory and did not need any attention for five years after this treatment. It was repainted, in the year 1930 and until last year when regular patching of the surface was started, it did not need any attention.

Road improvement by grouting and premixing methods was first carried out in the year 1926-27 in a 1½ mile length of an important section of Qutab Road. Three different specifications were tried with highly satisfactory results These were (1) Grouting with Mexphalte (2) Grouting with Trinidad Asphalt cement (3) Premix with Trinidad asphalt cement using cement as filler. The real advance however, began in 1930-31 when no less than 450,000 square feet of road surface were treated with bitumen, and there is now a total of 600,000 square feet of this.

Heavy two and four wheeled bullock carts impose a very great strain on the road surface. These carry 2 to 3 tons and are drawn by 2 or 3 bullocks or buffaloes. The wheels and axles seldom fit and often have an oscillating motion which is very destructive. Further the tyres are often narrow and have a curved cross section, thus the area of the wheel

in contact with the road is much less than it should be. On roads subject to intense traffic of this nature surface treatment with bitumen has been found to be inadequate and recourse has been had to grouted and premixed treatments.

The methods that have been in use in recent years include:—

I. *Grouting with hot asphalts.*—Before spreading the metal, the road surface is cleaned of all foreign matter. The metal used is 1½ inch to 3/4 inch gauge, clean, dry and free from clay or dust and uniformly spread to the correct depth. The loose metal is half an inch more in thickness than the finished coat, *i.e.*, for a 2 inch coat metal is spread 2½ inch thick.

The old surface of the road is first picked up and relaid to correct camber and grade. The stone metal is not dumped on the road surface but to ensure uniformity of spreading is stacked at the road side. Irregularities in spreading are carefully looked for and corrected by hand packing. Templates are used at short intervals with strings stretched between them as a guide. This is all done before rolling, as it is difficult later on to correct irregularities and experience has shown that unevenness of surface and weak spots are mainly due to uneven spreading. A ten ton roller is used on the dry metal. Rolling is commenced at the sides and advances towards the centre by successive stages of at least half the width of the roller until the surface is uniform and compact.

During the winter months bitumen (Mexphalte 30/40) does not penetrate into the interstices more than an inch owing to the quick fall in its temperature on coming in contact with stone metal. This difficulty is overcome by spreading the metal for a 2 inch coat in two layers of 1¼ inch each. Half the quantity of bitumen is used in each layer. Rolling is started as soon as the second layer has been grouted and the chippings have been spread.

Bitumens.—The bitumens used during 1933-34 on Sections the Grand Trunk Road towards the U. P. were Socony Asphaltum 101 and Mexphalte 30/40 penetration, separate sections being grouted with each. Pouring cans were used for Socony Asphaltum and a sprayer for Mexphalte. The bitumens were uniformly heated in suitable boilers to 350°F.

The length of road to be covered by the contents of each pouring can was marked out and this was further checked by observing the area covered by the contents of the boiler. Bitumen was used at the rate of 1 gallon per square yard, of 2 inch finished coat.

Stone grit.—Stone grit 3/4 inch to ¼ inch gauge was spread immediately after the application of bitumen in sufficient quantity to fill the surface voids and prevent the roller from picking up the bitumen. Care was taken to see that the stone grit was spread uniformly and all voids filled up. When rolling commenced one labourer followed the roller to cover with grit any surface where bitumen appeared.

Seal coat.—A seal coat was applied directly after the rolling had been finished. The surface was brushed and all loose and surplus grit was removed. A bitumen of 80/100 penetration was used either Socony Asphaltum grade 105 or Spramex in the sections grouted with Socony Asphaltum 101 and Mexphalte respectively. The bitumen was sprayed (not poured) at the rate of 3 gallons per 100 sft. followed by stone grit ½ inch to ¼ inch gauge for blinding. The surface was again thoroughly rolled. The surface thus treated was opened to traffic and a labourer was

deputed to brush over the blinding as and when disturbed by traffic. The grit and stone metal used on the work were hard blue quartzite stone obtained from the Delhi Ridge quarries.

II. Grouting with cold emulsions.—Spreading of metal, rolling and pouring was as for hot grouting. A section of the same road was treated by this process. The Emulsion used was Colfix. It was at first found to penetrate too rapidly to the bottom of the metal and thus failed to bind the aggregate effectively. To prevent this the voids in the stone metal were filled with grit of $\frac{3}{4}$ inch to $\frac{1}{4}$ inch gauge spread before grouting. This resulted in a slight improvement and although the emulsion did not properly bind the stones, it, however, held them together and made compaction of the layer possible. The road was opened to traffic after twenty four hours, and any weak spots that appeared were picked out and repaired.

A week later, a seal coat was applied after brushing the surface clean. Prior to sealing all pot-holes were properly made up. A sprayer was employed for spreading the emulsion evenly over the surface. Stone grit $\frac{1}{2}$ inch to $\frac{1}{4}$ inch size was evenly spread and traffic was allowed over the road after 24 hours. The result of this treatment was not satisfactory as the surface became uneven and many pot-holes were formed soon after the traffic started to use it.

III. 1 inch to 3 inch premixed asphalt macadam.—This specification was tried on the same road using both cold Emulsions and hot Asphalts as described below:—

(1) With cold emulsions.—The aggregate used was quartzite stone metal as noted below:—

For 1 inch pavement 100 per cent passing 1 inch screen and retained on $\frac{3}{8}$ inch.

For $1\frac{1}{2}$ inch pavement 100 per cent passing $1\frac{1}{2}$ inch and retained on $\frac{1}{2}$ inch.

For 2 inch pavement 100 per cent passing 2 inch and retained on $\frac{1}{2}$ inch.

For $2\frac{1}{2}$ inch pavement 100 per cent passing $2\frac{1}{2}$ inch and retained on $\frac{3}{4}$ inch.

The fine aggregate for the wearing coat of the thicker pavements was of smaller size than that specified for the bottom course.

Bitumen.—Socony Asphalt Emulsion Nos. 3 and 6 were used.

Method.—The base was made true to grade and camber and thoroughly cleaned and a priming coat of Socony Asphalt Emulsion No. 3 was applied at a rate of 2 to 3 gallons per 100 square feet. The coarse aggregate for the bottom course was mixed with Emulsion No. 6 by dipping. The quality of the Emulsion must be such that between 4 and 6 per cent by weight of bitumen will be incorporated with the stone Socony Emulsion No. 6 containing 70 per cent of bitumen met this requirement.

The coated coarse aggregate was spread on the prepared base to a thickness of about half an inch more than the required finished thickness. After spreading it was left for six hours and then rolled to compaction with a ten ton roller. Fine stone grit was spread over the surface to prevent adhesion. Rolling was continued until all movement had ceased.

Seal coat.—In the case of 1 inch and 1½ pavements a seal coat was applied using 2 to 3 gallons per 100 sft. with stone grit of ½ inch to ¼ inch gauge at the rate of 3 cft. per 100 sft.

For 2 inch to 3 inch pavements a wearing course was used of ¾ inch stone grit dipped in the emulsion and spread evenly, after raking over the bottom course, uniformly to a depth of ¾ inch. This was rolled, after three hours, stone dust was added on the surface to obtain a closed finish. The result of this process of premixed asphalt Macadam was not very satisfactory.

2. *With hot bitumen asphaltic concrete (shelcrete and shelsheet).*—The bituminous materials in this case were Mexphalte 20/30 penetration and "Shelmac", a "cut back" made by the Shell Company with bitumen and Solar oil. A "cut back" of this type is relatively simple to manipulate and easy to work. It needs only slight heating and the mixed aggregate can be laid either cold or hot immediately or be stored. If after some time it gets hard, it can be softened by the addition of a little Solar oil.

The grading of the aggregate was varied according to the thickness of the coat. For 1 inch Shelsheet the stone was of ¾ inch to ¼ inch gauge and for thicknesses of 2 and 2½ inch, of 1½ inch to ½ inch gauge. Sand containing 9 per cent coarse (−2 mm+·6 mm), 80 per cent medium (−·6 mm+0·2 mm), 6 per cent fine (−0·2 mm+·085 mm), and 5 per cent dust (−·085 mm) was used. In damp or cold weather the sand was heated to about 110°F on iron sheets six inches above ground level with a fire underneath.

Shelmac (one part) was heated to about 200°F and the Mexphalte 20/30 (two parts) to 350°. The mixture was raised to 350°F and allowed to cool down to 300°F at which temperature it was used.

For a 2½ inch finished coat (Shelcrete) batches of 3 cft. of stone metal of 1½ inch to ¼ inch gauge and 1½ cft. sand were used with 22½ pounds of the mixture of Mexphalte and Shelmac. The surface of the road was first brought to the proper camber and grade and all pot-holes were filled in, stone metal coated with bitumen without sand being found very satisfactory for this.

A Millar's Mixer of 5 cft. capacity was used as follows:—

The machine was started up and the stone put in. Nine pounds of bitumen was added and when the metal was coated with bitumen 1½ cft. of sand was put in followed by 13½ lbs. of bitumen. Mixing was carried for 3 minutes. The mix was carried to the road in iron barrows, dumped and immediately spread by rakes to the screeds. Rolling followed without delay with an eight ton roller. The resulting surface after compaction had a mosaic appearance at first but quickly closed up under traffic. It is in effect self sealing.

1 inch Shelsheet.—For this the process was the same except that smaller gauge stone was used and greater care was necessary that the base should be properly prepared and even. These thinner carpets tend to follow the unevenness in the base if this is not done. For details see page 6.

The total area treated during the year 1933-34 with the specifications described above was approximately 500,000 square feet. The roads treated

carry medium traffic and intensive cart traffic. These were Hamilton Road, the City approach to the Jumna Bridge and sections of Delhi-Gurgaon Road *viâ* Basant, Traffic statistics are being collected.

2½ inch thick Shelcrete was laid for heavy cart traffic and 1 inch Shelsheet for lighter traffic. No expenditure has been incurred in the maintenance of the Shelcrete but some patching has been necessary with the Shelsheet.

Brick and occasionally cement concrete edging has been laid along roads treated with bituminous mixtures in order to define and protect the edges.

Tar.—Tar has also been used both for surface painting and for carpets. The surface painting done was similar to single coat bitumen painting and appears to be only suitable for light traffic. For carpets the method adopted was that of a single coat of graded stone metal final dressing being done with premixed chippings of ½ inch to ⅛ inch gauge.

Tar carpets or pavement have been laid of 1 inch, 1½ inch and 2½ inches thickness, the first on an old painted road, the Alipur Road, the second on an old water bound Macadam road, the Grand Trunk Road to Karnal and the last on the Old Rohtak Road.

The grading of the stone metal was as follows:—

For 2½ inch and 1½ inch pavements.

1½ inch	to	1 inch	30 per cent.
1	„	½ inch	35 per cent.
½	„	⅛ „	30 per cent.

Stone dust filler 5 per cent.

For 1 inch Carpets.

1 inch	to	¾ inch	35 per cent.
¾	„	½ „	30 per cent.
½	„	⅛ „	30 per cent.

Stone dust filler 5 per cent.

The tar used was a low viscosity B.E.S.A. specification No. 2.

The method of mixing, storing, spreading and rolling was as follows:—

Mixing was usually done by hand in old tar drums fixed on a wooden frame and rocked by 4 workmen—2 cft. were mixed at one charge in 5 minutes and 3 such mixing drums turned out about 720 cft. daily. The quantity of tar was 2½ lbs. for 1 cft. of large stone and 3 lbs. for 1 cft. of chippings. The tar was heated to 250°F and the stone metal and chippings were separately mixed and stored at road site exposed to the air for 7 to 14 days and not used until the mixture had become sticky. In the hot weather this condition was reached after only 2 or 3 days and the mixture was laid and rolled then.

Mixture was spread to the required thickness on a road surface which had been given a priming coat of No. 1 Tar at the rate of 1 gallon for 50 to 80 sft. It was then rolled till movement ceased. The premixed chippings were then spread and rolled lightly for four or five times only.

The road was opened to motor traffic after 48 hours and to cart traffic after 4 days. In summer the road should not be opened to traffic for 10 or 12 days. No priming coat was found to be necessary in the case of 2½ inch carpet.

In addition to the above work a further series of road surfaces have been laid recently which are of an experimental nature.

The reason for these experiments is to select materials and methods best suited to the needs of the traffic and to the financial resources available for the upkeep of the roads.

Our aim is to establish an equilibrium between the needs of the traffic and our resources.

Specification for Resurfacing with 1 inch Shelsheet laid on (1) Queensway D to X (2) Parliament Street D to Jantar Mantar (June 1934).

Material used.—Mexphalte 20/30 penetration and 'Shelmac' in the proportion of 2 of the former to 1 of the latter.

The initial operations of cleaning etc. were carried out as usual and the surface was pickmarked and dabbed at intervals with Mexphalte as a tack coat before laying Shelsheet.

Mexphalte (20/30 penetration) was heated to 350°F and Shelmac added to it, the temperature of the mixture being kept at 300°F.

The aggregates used were stone grit passing 1 inch mesh and retained on ¼ inch and fine Badarpur sand, in equal proportions.

The stone grit was first put into a Millar Mixer and was stirred over with a few turns of the machine before the prepared bitumen mixture was poured over the grit at the rate of 3 lbs. per cft of grit. The machine again ran for a few turns till the stone grit was covered with the mixture then an equal quantity of Badarpur sand was added with the machine still working and after a few turns bitumen mixture at the rate of 9 lbs. per cft. of the Badarpur sand was added. When the sand and grit, thus mixed, were thoroughly coated with the bitumen the mixture was taken out of the mixer into wheel barrows and from them spread on the road to an average thickness of 1¼ inches while still hot, and thoroughly rolled with an eight to ten ton steam road roller. The road was opened to light traffic almost immediately but carts were not allowed on it for two or three days.

Cost.—Rs. 9 per hundred square feet.

Specification of Resurfacing with 1 inch Tar carpet.

laid on (1) Parliament Street T to H/2 and Circle T.

(2) Queensway B to E and E to S 2.

(3) Raisina Road X Pt. to Great Place.

The old surface of the road having been properly cleaned was given a priming coat with Tar No. 1 heated to 250°F at the rate of 1/10th gallon to a sq. yd.

Stone grit passing 1 inch mesh and retained on 1/4 inch mesh was coated with Tar No. 2 heated to 250°F. at the rate of 2½ lbs. per cft of grit. The precoated grit was stacked at roadside for two or three days for the

light oil constituents to evaporate and to allow it to develop its adhesive qualities. It was then carted to the site of work and spread to an average thickness of 1¼ inches and rolled with an eight ton steam road roller. When the surface had been thoroughly rolled, stone dust was sprinkled on the surface to fill in the voids.

The road was kept closed to heavy bullock cart traffic for 10 days.

Cost.—1 inch Carpet Rs. 8 per hundred square feet.

Seal coat Rs. 3-8 per hundred square feet.

Specification for 1 inch Tar Carpet at Great Place (October 1934).

The method of laying the tar carpet slightly varied from the usual method for tar carpets and was based on successful experiments carried out in the Punjab.

Material—

Tar No. 1 at 240°F.
Tar No. 2 at 250°F.
Tar No. 3 at 260°F.

Construction.—After the usual operations of cleaning etc. the existing surface was primed by spraying with Tar No. 1 at the rate of 16 lbs. per 100 sq. ft. The metal was graded from ¾ inch to ⅛ inch in the following proportions:—

¾ inch to ½ inch 60 per cent.
⅜ inch to ⅛ inch 40 per cent.

This was premixed with Tar No. 3 at the rate of 2½ lbs. per cft. and spread on the surface while the priming coat was still "tacky". The premixed metal was spread to an even surface and consolidated by a roller.

After the expiry of 24 hours the surface was again painted with hot Tar No. 2 at the rate of 24 lbs. per 100 sq. ft. To obtain an even spread this was brushed immediately after the sprayer had passed.

Fine grit ½ inch to ⅛ inch at the rate of 3 cft. per 100 sq. ft. was then spread and rolled till the carpet had set, and the road opened to traffic.

Cost.—Rs. 10 per hundred square feet.

Armour coats.

These have been laid on the Karnal Road, Miles 3 & 4 (October 1934) with three different materials, *viz*:—

(*a*) Armourcoat with Bitumuls.
(*b*) Armourcoat with Colas Emulsion.
(*c*) Armourcoat with Tar-Bitumen Mixtures.

The materials and specifications used in armourcoat construction are as follows:—

(*a*) *Armourcoat with Bitumuls.—Materials.*—(*i*) Bitumuls Emulsion.

A quick setting type of emulsion is required in the construction of an Armourcoat.

(*ii*) Aggregates (Stone metal 1 inch to 3/4 inch).

The large aggregate is stone metal of which 90 per cent passes a screen having 1½ inch circular openings and not less than 90 per cent is retained on a similar 1 inch screen.

Coarse stone chippings used for key stone and filling voids is ⅜ inch to ⅛ inch and must conform to the following grading:—

> Not less than 80 per cent shall pass a ½ inch screen and not more than 5 per cent shall pass a 10 mesh sieve.

Fine chippings used for filling voids and for surface finish must conform to the following grading:—

> Not less than 90 per cent. shall pass ¼ inch screen and not more than 20 per cent. shall pass a 10 mesh sieve.

Preparation of Sub-grade.—The old surface of this section prior to the construction of the Armourcoat had an irregular cross fall. The camber varied between 1 in 36 and 1 in 20. The brick-edging had sunk into the ground lower than the metalled edge at many places. This necessitated truing up of the old surface so as to have a regular camber of 1 in 48. This was done with stone metal precoated with bitumuls which was also used for filling potholes and depressions after digging them out. The material thus laid was thoroughly well compacted and all dirt or dust completely removed from the rest of the road surface by brooming. It was then sprinkled with water and a tack coat of Bitumuls at the rate of 1/10th gallon per square yard was given on the damp surface.

The stone ballast was spread by hand on the prepared surface at the rate of 12·1 cft. per 100 sft. Dumping from baskets on the subgrade was not permitted. If the stone ballast segregated into sizes in handling, it was mixed until it presented a uniform appearance spread on the road. The surface of the stone was then carefully trued up and all high and low spots remedied by removing or adding stone as necessary. It was then lightly rolled once only to interlock the stones.

After the stone ballast had been rolled, a little water was sprinkled and on the damp metal bitumuls was applied with a pressure distributor at the rate of 2 gallons to 5 sq. yds. It was then left for at least 12 hours before rolling. Rolling must not be started until two pieces of the metal can be pulled apart without the asphalt stripping from either piece.

The Bitumuls treated aggregate was rolled over lightly once and immediately afterwards, coarse chips were uniformly spread on the surface in sufficient quantity to fill the voids (2 to 3 cft. per hundred sq. ft.).

These were spread by hand and then broomed to secure even distribution. The surface was then rolled the rolling being accompanied by brooming with a dragbroom until the chips were forced into the voids of the base stone and it became thoroughly locked and keyed.

Any loose chips remaining on the surface were evenly distributed by brooming and then a final application of bitumuls was made at the rate of 3 gallons to 5 sq. yds. An interval of 12 hours or longer was allowed before it was lightly rolled once again. The surface was then covered with fine chips at the rate of 1¼ cft. per hundred sq. ft.

The fine chips were spread, broomed and rolled in the same manner as described for the application of the coarse aggregate. The surface was then rolled until it was smooth, uniform, and fully compacted.

Cost.—Rs. 14 per hundred square feet.

The following specifications have been followed in two short lengths treated with Bitumuls WRM and Bitumuls and Tar.

1½ inch consolidated Premix with Bitumuls.

Base Course—

10 cubic feet stone metal graded as follows :—

1½ inch to 1 inch	5 cubic feet.
⅝ inch to ½ inch	2½ cubic feet.
⅜ inch down to dust	2½ cubic feet.
	10 cubic feet.

This aggregate was mixed dry and formed into conical heaps on the surface of the road to be treated.

One gallon of water was poured over each followed by 5 gallons of Bitumuls WRM and the whole turned over with shovels until thoroughly incorporated. It was left in heaps for 24 hours.

A Tack coat of the same emulsion was then applied to the surface at the rate of one gallon per hundred square feet. As soon as this had broken the premixed material was spread evenly to 1½ inch thickness and rolled to consolidation.

Wearing Course.—10 cubic feet of stone grit ⅜ inch to dust was placed in a heap and wetted with two gallons of water. Six gallons of Bitumuls WRM was then poured over it and mixed. It was left for twenty-four hours.

It was then spread evenly to half an inch thickness and rolled to consolidation.

The road was then opened to traffic.

1½ inch consolidated Premix with Bitumuls and Tar.

Base Course—

10 cubic feet of stone metal graded as follows :—

1½ inch to 1 inch	5 cubic feet.
¾ inch to ½ inch	2½ cubic feet.
⅜ inch down to dust	2½ cubic feet.

This aggregate was mixed dry and formed into conical heaps on the surface of the road to be treated.

Five lbs. of Tar No. I heated to 200°F, was poured over each heap and thoroughly mixed with shovels. This was followed by five gallons of Bitumuls WRM added cold and mixed until thoroughly incorporated. It was then left for twenty-four hours before spreading and consolidation.

The rest of the specification including Tack Coat and Wearing Course was exactly the same as for the plain Bitumuls premix.

(*b*) *Specifications of Armourcoat with Colas Emulsion*.—The details for correcting the camber and preparing the subgrade by patching potholes are the same as described under Bitumuls.

After this the old surface of the road is cleaned and then slightly roughened by wire brushes and by picking it lightly at short intervals. A chase was cut along the edges and bricks laid vertically.

If there is much camber on the road which would result in Colas flowing off the sides, a very thin layer of stone dust must be scattered on the road first.

Coarse stone ballast 1½ inch to 1 inch was then evenly spread at the rate of 12 cft. per 100 sft. or 1½ inch thick and lightly rolled with a hand roller.

After the initial rolling ¾ inch to ½ inch grit at the rate of 2½ cft. per 100 sq. ft. was spread to fill in the interstices to about ½ inch down from the surface.

The surface was now damped with water and Colas emulsion applied at the rate of ⅝ gallon per sq. yd. A sprayer was used and care taken to get even distribution of the emulsion. The surface was then blinded with ½ inch chippings at the rate of 4 cft. per 100 sq. ft. The surface was then made even by a dragbroom and very lightly rolled. This done, a little water was sprinkled and more Colas emulsion at the rate of ⅓ gallon per sq. yd. sprayed on. The surface was again blinded with ¼ inch to ⅛ inch screenings at the rate of 3 cft. per 100 sq. ft. and a drag-broom again used. The latter operation must be done very carefully as it is apt to pick up stones leaving small holes in the surface which, if not replaced by hand, will render the surface uneven.

After this the surface was left for 24 hours and was then thoroughly consolidated with a ten ton steam roller.

Immediately after the rolling and compaction of the armourcoat a seal coat of Colas at the rate of 1/5 gallon per sq. yd. was applied and blinded with stone dust ⅛ inch and less. Cost Rs. 12 per hundred square feet.

(*c*) *Specifications for Armourcoat with 1½ inch Tar/Bitumen Mixture*.—The details for correcting the camber and preparing the subgrade are the same as those described under Bitumuls.

The old surface of the road is cleaned and then slightly roughened by wire brushes and by picking it lightly at intervals. A chase is cut along the edges and bricks laid vertically to afford lateral support.

Materials.—The following two mixtures of tar and bitumen have been used :—

Mixture A 75 per cent Tar.
25 per cent Bitumen.

" B 70 per cent. Tar.
30 per cent. Bitumen.

The Bitumen used is Mexphalte 30/40 penetration and the tar is Shalimar No. 2.. The mixture is prepared at the works and brought to site in sealed iron drums.

Aggregate.—The aggregate of Delhi Quartzite was in the following proportions:—

1 inch stone	. . .	one-third.
¾ „ to 1½ inch	. .	one-third.
⅜ „ to ⅛ „	. . .	one-third.

The proportions of the chippings were

½ inch to ¼ inch	. . .	60 per cent.
3/16 inch to ⅛ inch	. .	40 per cent.

Mixing.—The three different grades of stone were separately stacked and, before mixing, measured quantities were taken from each of the stacks and were spread in layers one above the other. These layers were cut by a shovel so as to get equal quantities of each and carried to mixing drums. Mixing was done in revolving drums, the stone aggregate being put into them at atmospheric temperature and hot bitumen mixture at 250°F then added at the rate of 3½ lbs. per cft. in the case of Mixture A and 3 lbs. in that of B.

The capacity of the drum is 2 cft. and mixing is continued until the aggregate is thoroughly well coated. One drum turns out 60 batches of two cft. per day of 8 working hours.

Construction.—The precoated aggregate was then taken to the storage dump and allowed to cool down so as to develop the adhesive qualities of the bituminous material. About 2 to 3 days are considered necessary for this purpose after which the precoated aggregate is carried to the road surface where it is evenly spread with rakes.

The following specifications have been followed in 4 short lengths treated with Tar/Bitumen Mixtures A & B:—

1½ inch Consolidated Premix.

(*a*) ¾ furlong.

Base Course.

15 cubic feet metal per 100 sq. ft. premixed with 3 lbs. mixture "A" per cubic ft. of stone.

Surfacing Course.

Spread ½ inch—⅛ inch dry chippings at 4 cub. ft. per 100 sq. ft. and roll.

Wearing Course.

Seal by spraying Mixture "A" at 30 lbs. per 100 sq. ft. spread ½ to ⅛ inch dry chippings at 3 cub. ft. per 100 sq. ft. and roll.

Cost.—Rs. 15-8 per 100 sq. ft.

(*b*) $\frac{3}{4}$ furlong.

Base Course.

15 cft. metal per 100 sq. ft. premixed with 3 lbs. mixture "A" per cubic ft. metal.

Surfacing Course.

4 cft. chips per 100 sq. ft. premixed with $3\frac{1}{2}$ lbs. mixture A per cubic ft.

Cost.—Rs. 13-12 per 100 sq. ft.

(*c*) $\frac{3}{4}$ *furlongs.*

Base Course.

15 cft. of metal per 100 sq. ft. premixed with $3\frac{1}{2}$ lbs. Mixture 'B' per cft.

Surfacing Course.

Spread dry $\frac{1}{2}$ to $\frac{1}{3}$ inch chips at 4 cft. per 100 sq. ft. and roll.

Wearing Course.

Seal by spraying mixture 'B' at 30 lbs. per 100 sq. ft. blinded with 3 cft. chippings and roll.

Cost.—Rs. 16-4 per 100 sq. ft.

(*d*) $\frac{3}{4}$ *furlongs.*

Base Course.

15 cft. of metal per 100 sq. ft. premixed with $3\frac{1}{2}$ lbs. mixture 'B' per cft. metal.

Surfacing Course.

4 cft. of chips per 100 sq. ft. premixed with 4 lbs. mixture B per cft.

Cost.—Rs. 14-8 per 100 sq. ft.

N. B.—In (*a*) & (*c*) after the metal has been premixed, spread and rolled, dry $\frac{1}{2}$ inch—$\frac{1}{4}$ inch chips are spread at 4 cft. per 100 sq. ft. and rolled. These chips are not premixed with any Tar Bitumen mixture. After they are rolled in. a seal coat is applied at 30 lbs. per 100 sft. ($4\frac{1}{3}$ sq. yds. per gallon).

The quantities of metal actually used were in excess of those mentioned above because the thickness at the edges is more than $1\frac{1}{2}$ inches, in order to correct the camber.

Cost.—Rs. 15-8 per hundred square feet.

Specifications for resurfacing 1 inch Premix with cold Socony Emulsion, laid on Maude Road (August 1933).

Materials used.—Socony Emulsion No. 3 Bitumen content 55 per cent. of 105 grade and No. 6, 70 per cent. of 105 grade.

The road surface was first cleaned with wire and broom brushes.

After the cleaning operations a tack coat of Socony Emulsion No. 3 at the rate of 1½ to 2 gallons per 100 sq. ft. was applied to the clean surface.

Stone grit passing 1 inch mesh and retained on ½ inch mesh was placed in perforated buckets, which were dipped in larger buckets containing Socony Emulsion No. 6. These perforated buckets were taken out and, after the excess quantity of emulsion had run out, the material thus pre-mixed was laid on the surface to an average thickness of 1¼ inches.

After the breaking of the emulsion (when it assumed a dark colour) the surface was rolled.

After thoroughly rolling of the surface had reduced the voids to a minimum fine stone chips from ¼ inch downwards were sprinkled on the surface brushed even and rolled into the interstices and the road was opened to traffic.

About 5 to 7 lbs. of Emulsion were required to coat one cft. grit in the dipping process.

Cost.—Rs. 9 per hundred square feet.

Specification for Resurfacing with 1 inch hot Socony Premix.

Parliament Street Point P to O/4 including Circle H/2 (June 1934).

Material used.—Socony Asphalt, grade 101.

The old surface of the road was roughened with pick axes and was thoroughly cleaned.

Stone grit at atmospheric temperature, passing 1 inch mesh and retained on ¼ inch was mixed with Socony asphalt, grade 101, heated to 350°F at the rate of 3 to 4 lbs. of asphalt per cft. of grit. The mixing was done in a mixing drum fitted with beaters and operated by hand. The precoated grit was spread on the surface of the road to an average thickness of 1¼ inches and an interval of 12 hours was allowed before it was rolled to set. Fine stone chippings ¼ inch downwards were sprinkled, brushed and rolled into the insterstices and the road was opened to traffic.

Cost.—Rs. 9-8-0 per hundred square feet.

Specification for 1 inch carpet with Colfix, laid on Queensway Point X to B and Circus X Material used Cofix of 55 to 60 per cent. bitumen content (Spramex of 200 penetration).

The specification and the process of laying this were the same as used for cold Socony Emulsion, except that 6 to 8 lbs. of emulsion were required to coat 1 cft. of grit.

Cost.—Rs. 9 per hundred square feet.

Specification for 1 inch Premix coat with Ormul Emulsion laid on furlongs 6 to 8 of mile 5 Delhi-Muttra Road.

Material.—Ormul Emulsion, Stone grit passing 1 inch and retained on ½ inch mesh.

Construction.—The old surface of the road which had previously been treated with spramex about 2 years prior to this treatment had worn badly and had numerous potholes and depressions. These depressions were first filled with stone metal wetted and rammed and the surface damped.

A thin priming coat of the emulsion was applied to the surface at the rate of 1/5th of a gallon per sq. yd. A bottom coat of aggregate premixed with Ormul Emulsion by the dipping process, and consisting of stone grit passing 1 inch and retained on ½ inch was then laid. ¾ inch to ½ inch stone grit premixed with Ormul Emulsion was spread as a top course and rolled till no movement took place. About 5 to 7 lbs. of Emulsion are required to cover one cft. of stone grit in the dipping process.

The road was then opened to traffic after 2 days for a few days, after which the surface was cleaned and a seal coat applied. The road was then finally opened to traffic. This has definitely failed to stand up to traffic satisfactorily.

Cost.—Rs. 10 per hundred square feet.

Mix-in-Place treatment of Rohtak Road in 4 furlongs of mile 3 (March 1933).

Binders (A) "F. 70" and Mexphalte (30/40 penetration) in proportion of 3 to 1 in Furlongs 5 and 7.

(B) Colas Emulsion in Furlongs 6 and 8.

This section carries mixed traffic with intensive brick cart traffic. The road was remetalled in 1930-31 and the surface prior to this treatment had numerous deep pot holes.

Scarifying.—The surface was swept and cleaned by broom brushes and it was then scarified by means of the Caterpillar Grader and scarifier outfit No. 20 driven by a 30 H. P Tractor. The average depth up to which the road was scarified was 3". Owing to numerous potholes in the surface very considerable difficulty was encountered in the adjustment of the scarifier which continually required to be lowered or raised as it moved forwards and backwards on the road.

A trial was made with a "rooter" driven by a steam road roller, but this too did not prove very satisfactory. Employing hand labour for picking up the surface which the scarifying tynes had missed, proved more satisfactory.

Preparation of sub-grade.—The scarified material was bladed to one side of the road by means of a shovel-like attachment on the grader. The surface thus exposed was sprinkled with water and rolled.

First application of binder.—A mixture of "F. 70" and crude oil in the proportion of 3 to 1 by volume and heated to 200°F was applied to the surface at the rate of 4 sq. yds. to a gallon.

The bladed materials which had been graded by hand from 2 inch to $\frac{3}{4}$ inch by this time were brought to the road and laid in a regular window in the centre in sufficient quantity to give a wearing coat of 3 inch thickness. In grading the old ballast care was taken that all clay and fine materials were totally removed. As the old surface had been badly worn the quantity of old ballast obtained from it was not enough to make a 3 inch coat and new metal had therefore to be added. This was approximately one quarter of the total quantity used.

Second application of binder.—A mixture of "F. 70" and Mexphalte in the proportion of 3 to 1 was poured over the stack of new and old metal from hand pouring pots. This was done in two applications and the quantity of binder used in both was at the rate of $\frac{3}{4}$th a gallon per sq. yd. of finished road surface. The stone metal was then turned over and thoroughly mixed by the grader in a number of trips going forwards and backwards turning and shovelling the metal until it was fully coated with the mixture. The precoated aggregate was then spread evenly on the primed surface and was consolidated by a ten-ton steam road roller.

Stone chips $\frac{3}{4}$ inch to $\frac{1}{2}$ inch size were spread at 4 cft. per 100 sft. for blinding. No further rolling was done and traffic was allowed to go over the road for further consolidation.

Soon after completion the surface showed signs of breaking up and ruts formed. An effort was made to make the traffic spread evenly over the surface by putting guide stone boulders which proved fairly successful and the surface improved as regards smooth appearance for sometime. The defect appeared to be that the binder did not immediately become hard enough to bind the stones sufficiently to resist being pushed out under the weight of the traffic. Hence the surface became very wavy and rough.

It has however, now attained a hardness which is comparable with that of any of the heavy duty materials but still unfortunately retains the uneven surface.

The treatment using Colas Emulsion was exactly the same except of course that it was not heated.

The results were also the same.

Cost.—Rs. 15 per hundred square feet.

TREATING THE SURFACE OF A WATER BOUND MACADAM ROAD.

A.—Bitumuls wearing surface on Delhi Najafgarh Road, mile 2 F. 1 (Oct. 1934).

Material.—Bitumuls HX (55 per cent. Bitumen content of 200 penetration).

Construction.—The surface of the roadway was properly cleaned and all fine material was removed from the interstices of the base metal to a depth of at least $\frac{1}{2}$ inch.

Any holes or depressions which were revealed were patched with crushed metal precoated with Bitumuls HX.

First application.—After preparing the road surface a little water was sprinkled on to dampen the surface. Bitumuls HX was then sprayed on the surface at the rate of $\frac{1}{4}$ gallon per sq. yd. and this was

immediately followed by stone chips ¾ inch to ½ inch, which were spread on the surface at the rate of 3·3 cft. per 100 sq. ft. An interval of about two hours was allowed and then the surface was drag broomed and rolled.

Second application.—The surface was again damped by sprinkling water and a second application of Bitumuls HX at the rate of ¼ gallons per sq. yd. was given.

Immediately after spraying stone chips ⅜ inch to ⅛ inch were spread at the rate of 2·2 cft. per 100 sq. ft. After about two hours or a little longer the surface was dragbroomed and well rolled. the road was then opened for traffic.

Cost.—Rs. 6-8-0 per hundred square feet.

TREATING THE SURFACE OF A WATER BOUND MACADAM ROAD.

B.—Tar Bitumen Mixture wearing surface on Delhi-Najafgarh Road Mile 11 (Oct. 1934).

Material—

Mixture A.

Tar No. 2	75 per cent.
Mexphalte 30-40 penetration . .	25 per cent.

Mixture B.

Tar No. 2	70 per cent.
Mexphalte 30-40 penetration . .	30 per cent.

Construction.—The initial process of cleaning, etc., was carried out as in the case of Bitumuls wearing surface.

The Tar-bitumen mixture at 250°F was then applied by means of a sprayer at ⅓ and ¼ gallons per sq. yd. respectively of mixture A for 2 furlongs each and ⅓ and ¼ gallons of Mixture B for another 2 furlongs each, making up the total to a mile. After this application the surface was blinded with stone chippings ¾ inch to ½ inch at the rate of 3 cft. per 100 sq. ft. and rolled.

Cost.—Rs. 5-4-0 per hundred square feet.

II.—TREATING THE SURFACE OF PAINTED ROADS.

Tar-Bitumen Mixture wearing surface on Delhi-Najafgarh Road, Mile 6 (Oct. 1934).

Material—

Mixture A.

Tar No. 2	75 per cent.
Mexphalte 30-40 penetration . .	25 per cent.

Mixture B.

Tar No. 2	70 per cent.
Mexphalte 30-40 penetration . .	30 per cent.

Construction.—The old painted surface of the coat was properly cleaned and all dust and dirt was removed.

Tar-Bitumen mixture at 250°F was then applied by means of a sprayer at the rate of $\frac{1}{6}$ and $\frac{1}{8}$ gallons per sq. yd. respectively of mixture A for 2 furlongs each and $\frac{1}{6}$ and $\frac{1}{5}$ gallons respectively of mixture B for another 2 furlongs each, making a total of one mile.

The surface was then blinded with $\frac{1}{2}$ inch to $\frac{1}{8}$ inch stone chippings at the rate of $2\frac{1}{2}$ cft. per 100 sq. ft.

It was then rolled and opened to traffic.

Cost.—Rs. 2-8-0 per hundred square feet

Cement concrete Road—

1. *2 Furlongs on the old Rohtak Road (April 1934). ($\frac{1}{2}$ of F. 8 Mile 2, F. 1 and $\frac{1}{3}$ of F. 2 of Mile 3.)*
2. *2 Furlongs on the Meerut Road (October 1934). (Furlongs 2 and 3 of Mile 1.)*

The above concrete carriageways are of an experimental character and have been laid on sections of Provincial roads that are subjected to mixed traffic with intensive four-wheeled cart traffic. The former has been laid on an old macadam bed in a single course and the latter has been constructed as a double course, on a section which had received a grouting coat with an emulsion last year. This section soon after that treatment started breaking up and just before laying concrete its condition was so bad that it had to be closed to traffic. The stone metal did not effectively bind together but remained loose and crumbled away under the impact of the load resulting in a large number of depression all over the surface. The entire grouted coat had therefore to be removed to obtain a solid base under the concrete slab.

On the Rohtak Road to compare the resistance to such traffic of concrete with that of other high grade pavements one furlong lengths were constructed with $2\frac{1}{2}$ inch compacted coats of Shelcrete, Premixed Tar Carpet and Water Bound Tar Macadam. A detailed description of these is given in the preceding pages. It will be interesting to note how the degree of wear observed with these various experimental surfaces compares with that of concrete and to determine the economic life of each type.

For the concrete road a section 7″-5″-7″ has been adopted with a central construction joint and an expansion joint at 33 ft. intervals. A few bays have been constructed of the full width with straight and skew joints.

Two long bays of the full width of cross section have been constructed with an expansion joint only at the end of each day's work. Hoop iron hexagonal rings have been introduced $1\frac{1}{2}$ inches below the finished surface. It is expected that fine contraction cracks will occur following these hexagons and large cracks will be avoided. Edge reinforcement and M. S. dowels have been given in certain slabs. These various forms of construction are shown on the plan.

Materials.

Cement.—The cement used is slow setting Portland cement of BBB brand manufactured by Bundi Portland Cement Ltd. It passed the following tensile tests made by the manufactures with standard sand:—

Sand and cement ratio 3 to 1.

After 3 days	421 lbs. per sq. inch.	
After 7 days . . .	517	do.

The cement was supplied in jute bags and a certificate was furnished by the manufacturers showing that each consignment was tested and that it conformed in all respects to the British Standard specification for Portland cement.

The tensile tests made of each consignment on its delivery at the site of work gave the following results:—

Budya Nala sand and cement ratio 3 :1.

After 3 days	341 lbs. per sq. inch.	
After 7 days .	426	do.

The quantity of cement used was 635 lbs. per cubic yard of finished concrete.

Coarse aggregate.—In selecting the aggregate the various types of stone available were tested to determine toughness and hardness and degree of wear under wet and dry attrition tests. The aggregates vary a little in their granular structure, some being fine grained and others more coarsely crystalline. The supply has been obtained from four quarries, two being in Delhi, the Jhandewala and Ratia quarries and two at Tughlaqabad, the Lado Sarai and Maidan quarries. Each of these quarries yields a hard blue quartzite stone.

Test Results.

The results of tests which were carried out at the Government Test House, Calcutta, are tabulated below :—

Serial No.	Nomenclature of stone.	Particulars of quarry.	Percentage loss of weight in a Deval type attrition tester.		French coefficient of wear 40. Percentage loss of weight.		Specific gravity.	Remarks.
			Dry test on 11 lbs. of stone.	Wet test on 11 lbs. of stone with 1·1 gallon of water.	Dry test.	Wet Test.		
1	Slightly micaceous ferruginous quartzite.	Jhandawala quarry, Delhi.	1·1	3·7	36·4	10·8	2·6	The wearing quality of the stones will be fairly good both during the dry weather and the rains. But the rocks being rather brittle, will crush under a heavy load and so cause dust formation.
2	Ditto .	Ratia quarry, Delhi	1·6	4·0	25·0	10·0	2·6	
3	Ditto .	Maidan quarry, Delhi	1·6	4·0	25·0	10·0	2·6	
4	Ditto .	Lado Sarai quarry, Delhi.	1·6	3·4	25·0	11·8	2·7	

Notes on petrological examination by the Geological Survey of India.—The samples are all similar, being slightly micaceous and ferruginous quartzites. Though hard the rocks are rather brittle and will be crushed under a heavy load, producing a dusty road in the hot weather with potholes and a harsh surface during the rains. The rock is therefore not suitable as road metal, particularly with heavy traffic.

It will be noticed from these results that there is very little to choose between the local stone, the best being that from Jhandawala quarry. The results however suggest that unless a binder having high ductility is used these local stone metals are unlikely to stand up to heavy traffic. Further, as the wet attrition is much more marked than the dry, prevention of water soaking into the stone is very important.

Particular attention was given to the grading and cleanliness of the aggregate. The following sizes were found to give maximum density and minimum voids when mixed in the proportions given below:—

Passing $1\frac{1}{2}$ inch sq. mesh of standard wire screens and retained on $\frac{3}{4}$ inch	60 per cent.
Passing $\frac{3}{4}$ inch sq. mesh of standard wire screens and retained on $\frac{1}{8}$ inch	40 per cent

The above grading was followed for the single course construction. In the two course construction the grading was as follows:—

For lower layer—

Passing $1\frac{1}{2}$ inch sq. mesh and retained on $\frac{3}{4}$ inch sq. mesh . . .	60 per cent.
Passing $\frac{3}{4}$ inch sq. mesh and retained on $\frac{1}{8}$ inch sq. mesh . . .	40 per cent.

For upper layer—

Passing $\frac{3}{4}$ inch sq. mesh and retained on $\frac{3}{8}$ inch sq. mesh . . .	60 per cent.
Passing $\frac{3}{8}$ inch sq. mesh and retained on $\frac{1}{8}$ inch sq. mesh . . .	40 per cent.

The screens used for grading were of steel wire of which the gauge varied with the size of the opening as given below:—

1. Birmingham Wire gauge, No. 8, for $1\frac{1}{2}$ inch mesh.
2. Birmingham Wire gauge, No. 9, for $\frac{3}{4}$ inch mesh.
3. Birmingham Wire gauge, No. 12, for $\frac{3}{8}$ inch mesh.
4. Birmingham Wire gauge, No. 18, for $\frac{1}{8}$ inch mesh.

The percentage of voids in the single course aggregate after grading was found to be 38 and in that of the upper layer of two-course construction 42.

Fine Aggregate.—The sand was obtained from natural deposits in a ravine known as Budya Nala about 14 miles south of the city. This is free from loamy clay and organic matter. A little clay got mixed into it from the ground as suitable loading and unloading arrangements with pucca platforms did not exist. This necessitated washing which was done in running water and produced a very clean sand.

This sand was not as well graded as was desirable and to get a good dense sand it was blended with another sand from the same ravine in equal proportions. A screen analysis of each of these sands is given below.

No. I.

1. Passing 4 mesh and retained on 10 mesh 9 per cent.

2. Passing 10 mesh and retained on 50 mesh 84 per cent.

3. Passing 50 mesh and retained on 100 mesh 6 per cent.

No. II.

1. Passing 4 mesh and retained on 10 mesh 52 per cent.

2. Passing 10 mesh and retained on 50 mesh 40 per cent.

3. Passing 50 mesh and retained on 100 mesh 6 per cent

A mixture of equal parts of these two sands gave the following screen analysis using A. S. T. M. sieves:—

Passing 4 mesh and retained on 10 mesh . . .	30·5 per cent.
Passing 10 mesh and retained on 50 mesh	41·5 per cent.
Passing 50 mesh and retained on 100 mesh	6·0 per cent.

A graph of the sieve analysis of the mixture shows that it comes within the permissible limits of a standard sand.

Samples for crushing and tensile strength were made with this sand as well as with that of Pathankot for a comparison. The results are shown below:—

A.	Proportions.	Crushing strength tons per sq. in. after 9 days.
I.—Pathankot sand, stone grit aggregate and cement	1 : 1½ : 3	1·30
II.—Budhya Nala graded sand, stone grit aggregate and cement	do.	1·28

B		Crushing strength tons per sq. in. after 14 days.
I.—Pathankot sand, stone grit aggregate and cement	1 : 2 : 4	1·46
II.—Budhya Nala ungraded sand, stone grit aggregate and cement	do.	0·92

14 days tensile tests for sand and cement mortar in the proportions of 1 to 2 gave the following results:—

	Proportion.	
I.—Pathankot sand and cement . .	1 to 2	510 lbs. per sq. in.
II.—Budhya Nala graded sand and cement	1 to 2	415 do.

Pathankot is about 100 miles East of Lahore and 350 miles from Delhi. The sand is obtained from the Chakki river.

It is a mixed lime stone gravel and hard trap sand of grey or buff coloured particles. The good results that have been obtained in the tests made with this sand are due to its homogeneous nature and also to the well graded and well proportioned composition.

The main defect of the local Budhya Nala sand is that its particles are of a more uniform size and the volume of its voids is large.

A comparison is given below:—

1.	Void percentage in Pathankot sand	30
2.	Void percentage in ungraded Budhya Nala sand . .	31

By grading the sand between 10 mesh and 100 mesh the voids were found to be 28 per cent.

The results of tensile tests with graded Budya Nala sand were satisfactory, giving an average of 415 lbs. per sq. in. after 14 days. Those of Pathankot were 510 lbs. per sq. in. after the same period.

Water.—Care was taken that the water used was clean and available in adequate quantities. A continuous supply was maintained throughout the period during which the concrete was laid and cured. A pumping set was installed and a pipe line was laid with hydrants at short intervals. This ensured an efficient water supply.

The quantity of water per bag of cement was approximately 4·75 gallons during summer months and 3½ gallons during winter.

Occasional slump tests were made to check the consistency of the concrete. The slump was so little as not to be measurable but when actually laying the concrete it was found to yield an appreciable quantity of laitance on being tamped.

In addition to the slump test during mixing operations cylinder blocks 4 inches dia. by 8 inches long were made of the mixed concrete each day for compressive tests.

The results of 9 tests gave a mean compressive strength of 3675 lbs. per sq. in., the maximum being 5400 lbs.

Sub-grade work.—The old surface of the road was picked up where necessary to give a regular gradient to the concrete road and also to bring the base to the profile of the slab.

A layer of clinkers and ash was spread over the picked up rough surface of the subgrade. The average thickness of the layer was 2 inches. It was well rolled with a 12 ton roller with plenty of water. The surface, when dried, was hard, well set and even.

A thin layer of Jumna sand was then spread to prevent the cement mortar of the concrete running down into the clinker coat. The sand was kept moist by damping it with a watering can fitted with a fine rose.

Before laying the concrete iron side forms were fixed. Insufficient of these were available for the work in progress and brick walls 9 inches deep and 7 inches high, built in cement mortar and finished with cement plaster, were substituted. These were made true to the longitudinal levels. To ensure accuracy of the cross level and uniform thickness throughout the construction wooden templates were used.

Camber.—The cross fall from the edge of the road to a point 6 ft. from it is in a slope of 1 in 72 and the central portion is cambered to a curve.

Mixing and depositing.—Mixing was done by hand in batches using two bags of cement per batch of measured aggregate by volume.

Wooden boxes 12 inches by 12 inches, by 14 inches were used for measuring aggregate and sand to facilitate an accurate proportioning without having to measure cement.

For the single course construction in 1:2:4 proportions, each batch requires 4 measures of sand, 5 of 1½ inch broken stone aggregate and 3 of ¾ inch to ⅛ inch fines.

For the two course construction the batches for the lower layer were of the same proportions as for the single course. The batches for the upper layer required different measuring boxes. These were 12 inches by 12 inches by 21½ inches. In each batch two bags of cement required 2 measures of sand and 4 of aggregate.

Each batch was separately mixed and handled by the men allotted to it and the mixed materials were carried in iron pans and deposited in the bay under construction Water was added by measure using watering cans with fine roses.

Mixing platforms were arranged at such intervals that the period between the mixing of a batch and carrying it to the site did not exceed 15 minutes. The treatment of the concrete after depositing was a matter which required great care and attention.

The concrete for the bottom course in two course construction was placed directly upon the base and was thoroughly rammed as it was being deposited with cast iron rammers of 6 inches dia. and about 14 lbs. in weight.

This was done in order not to leave any voids and to spread it to the required shape. The top course was added within 15 minutes of the laying of the bottom course and was well tamped with a tamper. rigid and shaped to the true curve and cross slope of the camber. The tamper has a tamping edge 2 inches wide shod with a steel strip ¼ inch thick. Tamping was continued until all voids had been eliminated.

Immediately after finishing the surface the concrete was efficiently protected from the sun by tenting with canvas nailed to a wooden frame work and within 24 hours after depositing, the surface of the concrete was covered with canvas or empty jute bags which were kept wet.

The surface of the concrete was finished by means of a 4 ply bow belt 12 inches wide. This was about 2 feet longer than the width of the slab and stretched tight by means of a wire fixed to a wooden block at the end and was moved with a combined crosswise and longitudinal motion across the surface with a slight longitudinal advance. This belting was given to the finished surface of the concrete in order to produce a uniform surface finish with a gritty texture.

1. *Types of Construction.*—Long Bay construction with hexagonal hoop iron reinforcement rings.

The length of such bays was kept at 99 ft. and these were constructed of the full width of the road without a central joint. An expansion joint ½ inch wide was given at the end of each bay.

The method of construction was the same as that for a two-course concrete construction. The steel hoops were used in the surface layer in regular panels, the hoops being arranged alternately.

2. *Strip Construction.*—This method of construction has been largely followed both for single course and two-course construction and is from the construction point of view the simplest. It also affords facilities for controlling traffic by making it follow well defined tracks. It has the additional advantages of making it easy to obtain a true longitudinal grade and camber with short tampers and longitudinal forms.

Cost.—Rs. 58 per hundred square feet for 7"—5"—7" section.

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8 feet wide cement concrete and 16 feet wide 2½ inch Tar Carpet with seal coat and 2½ inch shel-crete laid in ½ furlong of furlong 8 mile 2 and ½ furlong of furlong 1 mile 3 on Rohtak Road.

The old surface of this road was badly worn and had numerous pot-holes. This necessitated picking it up to a depth of 8 inches and renewing it adding a 3 inch coat of new metal.

The width of the road in the section selected is 24 feet. This width was divided into strips 16 ft. and 8 ft. wide respectively.

The 16 ft. wide portion was brought to the required grade and camber as a water bound Macadam road to a level 2¼ inches below the proposed road level. The 8 ft. wide portion was similarly brought to a finished sub-grade surface with ashes, etc., as described under Concrete Roads at a depth of 6 inches below the proposed road level. To keep the exposed edge of the 16 ft. length as a truly vertical joint the last 1 ft. width on the side where the Cement Concrete road was to be laid was consolidated as a Cement Mortar bound road on the sandwich system against a steel form. After setting and removal of the steel form this vertical edge was plastered with cement plaster and the Cement Concrete strip laid against it.

Cement concrete in the proportion of 1·2:4 was laid in the eight foot strip with a 6—4—6 inch section having a camber of 1 in 72. ¾ inch expansion joints were provided at intervals of 33 ft. and filled with pre-moulded asphaltic filler. The general specifications for preparation of sub-grade, and mixing and laying of concrete were followed.

For ½ furlong the 16 ft. strip was treated with 2½ inch Tar carpet and a seal coat and the other ½ furlong with 2½ inch Shelcrete. The 2½ inch carpet coats of Tar and Shelcrete were laid according to their respective standard specifications.

This concrete with asphalt or tar carpet road was intended to carry heavy loaded bullock carts the concrete strip being on the left of the road in the direction in which most loaded carts travel.

Cost.—Cement Concrete 6"—4"—6" section 8 ft. wide . .	Rs. 34 per hundred sq. ft.
16 ft. wide 2½" Shelcrete or Tar .	Rs. 21 do.

Average cost.—Rs. 25 per hundred square feet.

Note on patch work with Socofix and Socofalt in furlong 8 of Mile 9 Rohtak Road.

Experiments with "Socofix" and "Socofalt" were carried out in small patches on Rohtak Road, where the old road had many deep potholes. Different patches were treated with different methods as follows:—

(1) The surface of the road after being cleaned was given a tack coat of the material. Stone grit $\frac{3}{8}$ inch to 1 inch precoated with the material at the rate of $\frac{1}{2}$ of a gallon per cft. was spread over it and this was then covered with Badarpur sand precoated with the material at the rate of $\frac{3}{8}$ of a gallon per cft. and rolled.

(2) The same method was followed as No. (1) but Badarpur sand was mixed with 10 per cent of fine filler (road dust).

(3) A small stack of stone grit sufficient for the patch was made, over which Socofalt was poured at the rate of $\frac{1}{2}$ gallon per cft. This was then mixed with a *phowrah*, till the grit was fully coated.

A tack coat was first applied on the patch and the precoated metal spread over it. It was then rolled with a hand roller and opened to traffic.

(4) The surface of the road was first painted and covered over with stone grit. It was then rolled before opening to traffic.

These materials have only recently been introduced and consist of Socony Asphalt mixed with different cut back oils in different proportions. They can be used cold like emulsions but have the advantage of a much higher bitumen content. Socofix hardens in a comparatively short time while Socofalt does so only after about 12-24 hours.

$2\frac{1}{2}$ inch Waterbound Tar Macadam coat laid on 1/2 furlong 4 and 1/2 furlong 5 of mile 3 Rohtak Road.

Material used Shalimar Tar No. 2.

The old surface of the road was badly worn and had developed numerous potholes. The surface was picked over to a depth of 3 inches and the material obtained was spread on the surface the screenings being at the bottom and the bigger metal on the top. New metal was added where necessary to make up the thickness of the metal to 3 inches.

This was lightly rolled, the purpose of rolling being to interlock the stones. A small quantity of fine clay was used to act as a binder. This done the roller was taken off and a layer of $2\frac{1}{2}$ inches of $1\frac{1}{2}$ inch metal precoated with Tar No. 2 at 250°F at the rate of $2\frac{1}{2}$ lbs. per cft. was spread while hot.

Before rolling, 4 cft. per 100 sq. ft. of $\frac{1}{2}$ inch to $\frac{3}{4}$ inch *bajri* precoated with Tar No. 2 at 250°F at the rate of 3 lbs. per cft. was spread while hot.

The road was rolled dry, till no movement took place. At this stage wet rolling was begun and continued until adequate compaction took place water being added gradually.

When consolidation was complete, the fine material from screening was spread over the surface and thoroughly washed in with copious water and allowed to stand for 24 hours to partially dry when a final light rolling was given.

Traffic was kept off the road for a week and the road was kept wet for 2 weeks more. A seal coat was applied after two months using Tar No. 2 at the rate of 15 lbs. per 100 sq. feet. The seal coat was not originally specified but was done because the surface showed signs of breaking up.

Cost.—2½" Tar carpet Rs. 18-8 per hundred square feet.

Seal coat Rs. 2-8 per hundred square feet.

2½ inch premixed coat with Hot Socony Asphalt laid in furlongs 2 and 3 of Mile 1 of Meerut Road.

Materials—Bitumen.—Hot Asphalt grade 101 of Standard Vacuum Oil Co., with a cut back.

Aggregates.—For binder coat. 1½ inch to 1 inch stone metal.

For Wearing coat. ¾ inch to ½ inch stone grit.

Preparation of Base.—This section of the road had been given a coat of two inches metal grouted with Colfix Emulsion in the year 1932-33 which soon after laying showed signs of deterioration and gave way under the weight of intensive brick-cart traffic which this section carries. It was in such bad order as to necessitate complete removal before laying the premixed coat. The base, after removal of the grouted layer showed many loose spots which where picked out. Prior to laying the premixed coat, they were carefully filled up with premixed aggregate, levelled up and rolled so as to form a hard base.

Preparation of Premix—The Asphalt (Socony 101) was heated in a tar boiler to 350°F and the correct quantity at the rate of 3 lbs. per cft. of stone metal was drawn off from it into a bucket. To this was added a cut back, Socosol, at the rate of 1 oz. to every 1 lb. of Asphalt.

The cut back was made by mixing Socony Asphalt 105, of 80—100 penetration and Kerosene oil. The Asphalt was heated to 250°F in a tar boiler and was drawn off into a container in which it was mixed with Kerosene oil in equal quantities by volume.

The aggregate was mixed in locally made drum mixers mounted on a wooden frame work. Each mixing drum had three mixing arms fixed inside which prevented the aggregate from sticking together.

The mixture of Hot Asphalt and Socosol 6 lbs. weight was poured over the 2 cft. of stone metal in the drum which was then rotated by two men 150 times, after which the premixed material was taken out and carted in wheelbarrows to the site of work.

Construction—

Binder coat.—The premix was evenly spread on the road to an uncompacted depth of 2 inches and rolled by a steam roller till no movement took place.

Wearing coat.—Stone chippings ¾ inch to ½ inch size, mixed with fine dust in equal proportions were premixed in the same manner as described above and spread on the binder course to an uncompacted depth of 1 inch, and consolidated.

Fine stone dust was then spread on the surface and the road opened to traffic.

Cost.—Rs. 17-8 per hundred square feet.

Specification for 2½ inches Trinimac laid in furlong 3 Mile 3 of G. T. Road to Meerut.

Material.—Trinimac Asphalt cement is prepared by mixing Trinidad Lake Asphalt and flux oil by taking 80 parts of the former and 20 of the latter. The flux oil is a residual product of Petroleum distillation and should have a flash point of 400°F.

To prepare the Asphalt cement, the Lake Asphalt is heated in a tar boiler to a temperature of 250°F and the flux oil is gradually added, the contents being thoroughly stirred so as to ensure complete incorporation of the asphalt with the flux oil.

Aggregate.—For binder course 2 inches to ½ inch.

Wearing surface. ½ inch to dust.

General Remarks.—This section of the road was treated with Premixed course of Socony Emulsion varying from 1 in. to 8 inches in thickness. The surface, however soon after that treatment disintegrated and it became necessary to remove it completely before laying the Trinimac.

Construction—

Binder Course.—The Trinimac Asphalt cement prepared as above was heated to a temperature of 350°F in a tar boiler, and drawn off into a bucket and mixed with aggregate in a rotary mixer, the stone aggregate being at atmospheric temperature.

4·8 lbs. of Asphalt cement were required per cft. of stone aggregate to completely coat every particle of it. As soon as mixing was complete the Trinimac was taken out of the mixer and carried to the site of work, where it was stacked and used cold. It was evenly spread on the prepared base to an uncompacted thickness of 2½ inches. It was then rolled to complete consolidation with a steam road roller.

Wearing surface.—The proportion of aggregate to asphalt cement was the same as in the Binder Course. The wearing surface was spread immediately after the consolidation of the binder course and was rolled to final consolidation. The total compacted thickness of the two courses was 2½ inches. The finished surface was then dusted over with stone dust and a final rolling given before opening the road to traffic.

Cost.—Rs. 22-4 100 sq. ft.

Specification for Stanotread treatment of ½ furlong of furlong 2, furlongs 3 and 4 and ½ furlong of furlong 5 mile 6 of Muttra Road.

Materials.—Socony Asphalt grade 105.

Socony Emulsion No. 3.

The existing road surface was properly cleaned, and all potholes of 1 inch depth or over repaired with precoated aggregate.

Socony Asphalt grade 105 was sprayed at the rate of 50 to 60 lbs. per 100 sq. ft. on the prepared surface. and stone metal passing a 1¼ inch circular mesh and retained on a ¾ inch mesh was broadcast on to the hot Asphalt at the rate of 12 cft. per 100 sq. ft.

This coat was lightly rolled and metal added or removed as necessary to get an approximately true surface. A further 5 to 6 cft. per 100 sq. ft. of stone chips passing ⅜ inch mesh was then spread, and rolling commenced with a heavy dragbroom attached behind the roller.

During rolling and dragbrooming more chips were added as necessary wherever the texture of the surface indicated a shortage. When the surface texture was absolutely uniform, it was treated with 3 gallons per 100 sq. ft. of Socony Emulsion No. 3 and left for 3 to 4 hours without disturbing the surface in anyway.

Finally, a little fine grit was spread over the surface, which was again rolled and dragged before being opened to traffic.

Cost.—Rs. 11 per hundred sq. ft.

Trackways on an earth road.

Badli Road.—This earth road of the ordinary village type which in a length of 6 furlongs from the Karnal Road to Badli Railway Station has been bridged and graded was selected for improvements with various tracks laid direct on the earth formation. The traffic on this road is almost entirely village carts from the neighbouring villages. During the rains when all other tracks in the vicinity are submerged, this road gives the only access to the Main road.

The following tracks have been laid:—

(1) Bharatpur stone slabs 4 inches thick in a 200 ft. length.

(2) Plain Cement concrete tracks 6 inches thick in 1½ furlongs.

(3) Cement concrete tracks with reinforcement of mild steel bars at top and bottom in 1/2 furlong.

(4) Plain cement concrete tracks 6 inches thick inlaid on top with 1 inch Shelsheet in 1 furlong.

(5) Cement concrete tracks with M. S. reinforcement at top and bottom inlaid with 1 inch Shelsheet in 1 furlong.

(6) Cement concrete tracks 3 inches thick over 6 inches lime concrete in 1 furlong.

(7) Cement concrete tracks 3 inches thick over 6 inches lime concrete inlaid with 1 inch Shelsheet in 1 furlong.

Preliminary preparation.—In the first 900 ft. length, the embankment was raised by a few feet. This was done to keep the formation level above the highest flood level which was higher than the original formation level of the bank.

The earth was laid in layers of 1 foot thickness and each successive layer was thoroughly well watered and consolidated with an eight-ton roller

Types of Construction.—(1) *Bharatpur stone slabs.*—These slabs are 4 inches thick and 8 to 10 ft. long and have been laid on the ordinary soil. The clear space between them was 3 ft. Before laying these slabs the earth was dressed, rammed and watered. Plain butt joints were given at the ends of the slabs.

(2) *Plain Cement Concrete tracks.*—In constructing the tracks iron side forms were used. These were laid for the full track and both the strips were concreted at the same time. The side forms were held in position by long iron pegs let down into the ground and by wooden struts which served both for gauging and resisting any inward movement of the forms.

Prior to laying the concrete, the earth was thoroughly rammed and watered and a thin layer of fine sand was spread uniformly and damped.

Aggregate.—The coarse aggregate consisted of the following grades of stone ballast:—

(1) Passing $1\frac{1}{2}$ inch and retained on $\frac{3}{4}$ inch 60 per cent.
Passing $\frac{3}{4}$ inch and retained on $\frac{1}{8}$ inch 40 per cent.

(2) Passing $\frac{3}{4}$ inch and retained on $\frac{3}{8}$ inch 60 per cent.
Passing $\frac{3}{8}$ inch and retained on $\frac{1}{8}$ inch 40 per cent.

Fine aggregate.—The sand was taken from Budya Nala and was a sharp, clean and hard quartzite sand. Two grades were required to be combined to produce a sand with the standard grading. See details of concrete Roads.

Mixing.—The mixing was all done by hand, Brick platforms were laid out at suitable points in each furlong and the required quantities of material were collected in advance of the work. The water was drawn from wells situated about half a furlong away from the road and sufficient quantity was stored in Tanks erected at three places at almost equal distances in the whole length of the road. The water was clean and free from deleterious matter.

The general details of the work were precisely the same as have been described in the note on concrete roads.

(3) *Cement Concrete with reinforcement.*—The general details of construction in this type of construction were the same as for the plain cement concrete. The reinforcement steel consisted of four mild steel round bars $\frac{1}{2}$ inch diameter placed at the bottom 2 inches above the base and five mild steel bars four feet long and of the same diameter at each end of the strip. The bars were suspended by wire and kept at the correct distance apart by using wooden templates.

(4) *Plain Cement Concrete inlaid with 1 inch Shelsheet.*—In this type of construction the upper surface of the track strip was depressed by one inch leaving a 3-inch concrete edge on either side during construction. The depressed surface was kept rough and diagonal lines were also made in it at short intervals. This was done to prevent the Shelsheet from being pushed under traffic.

(5) *Cement Concrete Track with reinforcement and inlaid with 1 inch Shelsheet.*—The details of construction of this type are the same as of 3 and 4.

(6) *Cement Concrete tracks 3 inches thick over 6 inches lime concrete.*—In this type of construction the general details were the same as

in other types. Prior to laying cement concrete a bed of lime concrete was laid. The side forms were made with 9-inch dry bricks laid flat and 6 inches high.

The lime concrete consisted of mortar of one part of slaked lime and three parts of Badarpur sand and Delhi quartzite stone aggregate passing a $1\frac{1}{2}$-inch screen. 40 per cent. by volume of wet mortar was added to the aggregate. The cement concrete top coat was laid after the lime concrete had well set. Before laying it the surface of the lime concrete bed was roughened to give a bond.

(7) *Cement Concrete tracks 3 inches thick with 6 inches lime concrete inlaid with 1 inch Shelsheet.*—In this type of construction the details of the work are the same as described above. The upper surface was constructed in the same manner as type 4.

Joints.—The joints are 33 feet apart and were filled with premoulded asphalt filler.

The tracks on completion were kept wet for 14 days. The space between them was filled with earth and the sides were made up and thoroughly well rammed with hand rammers.

Traffic was allowed on the road after the earth work was completed.

The premoulded asphalt filler was prepared as follows:—

Expansion on concrete roads has been provided for by $\frac{3}{8}$ inch expansion joints filled with premoulded Mexphalte joint filler. This filler has been made locally from Mexphalte, Jumna sand and Sawdust.

The Mexphalte was heated in an iron pan to a temperature of 250°F. A mixture of sand and Sawdust in equal proportions was gradually added and the whole thoroughly stirred, till the material became stiff. The quantities required for making 20 Joint fillers four feet long, 6 inches wide and $\frac{3}{8}$ inch thick were one cubic ft. each of sand and Sawdust and 5 gallons of Mexphalte heated to 250°F.

The material was poured out into wooden moulds each four feet long and six inches wide and lined with paper. It was rolled with a wooden roller and dressed to shape. The strips of the filler were then buried in sand where it hardened and was then ready for use. It can be cut as desired.

The filler was placed against the face of the concrete of the bay already laid at the joint and concrete of the next bay was laid against it.

Specification for applying seal coats.

Seal coats have been provided on some of the roads to prolong the life of the road surface. Various materials have been used for this purpose including Colas, Colade, Shelmac, Spramex and Tar

The potholes and depressions in the road were filled in and repaired by patching before starting the work. This done the surface was thoroughly cleaned free from dust and the sealing material spread on it at the rate of 3 gallons per 100 sq. ft. The surface was then immediately covered with $\frac{3}{8}$ inch stone grit evenly spread at the rate of 4 cft. per 100 sq. ft. and carefully rolled with a steam roller and opened to traffic.

Mr. A. W. H. Dean (the Author): The tourist map of Delhi, which you have all been given this morning, has got on it first of all a reference to a whole series of different specifications to which roads have been surfaced and to the corresponding number as marked in red on the map. This will enable you to inspect any roads independently, if you find time and the desire to do so.

I have a little additional information in regard to the costs which I will be able to give any of you who want it as we go round—costs of our stone metal and costs of carting—which will be useful for comparison.

There is one other point which I am a little diffident in mentioning but which I feel is something that ought to be cleared up, and that is, the ordinary nomenclature to be used in describing work on roads. When I was going round on this tour, I heard people talk of gallons per square yard, pounds per square yard, tons per mile, and so on. Here I have tried to confine myself to pounds per 100 square feet. The yard is not by any means generally used in India as a unit of measurement. We measure our metal in units of 100 cubic feet and our areas in units of 100 square feet. I feel that the yard is a unit which might be dropped. I have got a few figures also converting my units into tons per mile, which I can give as we go round to any people who are more familiar with that method of describing what they do.

There is one additional thing which I have been asked to show people as we go round and that is a method of using waste bituminous metal dug up from roads. We found that we had a few comparatively unsuccessful experiments where we had to dig out the surfaces, and also, on other occasions, we allowed roads to be almost completely destroyed in order to see what their life was, and we had to dig them up. We had thus got a lot of waste bituminous metal which we have been using for paving our side walks. There is a specimen near Maiden's Hotel. It has been there for ten months and it seems fairly satisfactory. What we do is this. We take 400 pounds of bituminous scrap and heat it in an old drum with an opening along the top, about 18 inches wide, and when it is fairly hot, and has been stirred, we put in a varying quantity of crude oil—about 2 or 3 pounds. In the hot weather we find that this is not always necessary, but in the cold weather it has to be fluxed with a small quantity. We then add 5 pounds of bitumen, and it is then taken out in closed carts as hot as possible and spread on the levelled earth surface of the side walk and trowelled to about an inch thickness. That is going on on one of the roads that we shall go over, and I have been asked to show that also to the Congress, although it is not mentioned in itinerary or in the notes.

Chairman: There is nothing else, gentlemen. We assemble here at 2-30 P.M. for an inspection of roads. There is one point which I might suggest to Mr. Dean, and that is, in going round, he might indicate how the different work is financed. My reason for suggesting that is that part of the work which is carried out is, as Mr. Mitchell has explained, for experiment. Some of the roads are roads belonging really to the Municipal Committee. We act as agents in maintaining them. Some roads are in the Chief Commissioner's charge. I think it would be useful if Mr. Dean could indicate which is which, so that people may understand why it is that in different places we are trying the same thing.

The Congress then adjourned for lunch.

The Congress reassembled at the New Delhi Town Hall after lunch and proceeded on an inspection of roads according to the following itinerary:—

Route.	Nature of surface on road to be inspected.	Ref. to Paper No. 1A.
Leave New Delhi Town Hall *viâ* Welseley Road to Muttra Road, Mile 7.	2½" Shelcrete . . . . . 1" Carpet with Ormul Emulsion .	24 34
	Stanotread Treatment . . .	47
Return *viâ* Delhi Gate, Elgin Road Jumna Bridge to Meerut Road, Mile 4.	Shelcrete } On Jumna . Tar Carpet } Bridge.	24 26
	Concrete Road	37
	2½" Hot Socony Premix . .	46
	2" Grouting with Hot Asphalts .	22
	2½" Shelcrete	24
	2½" Trimimac	47
Return New Delhi	....	..
Leave New Delhi Town Hall .	1" Carpet Shelsheet . . .	26
Parliament Street	1" „ Hot Socony . . . 1" „ Tar No. 2 . . .	33 26
Great Place	1" „ Tar No. 3 . . .	27
Raisina Road	1" „ Tar No. 2	26
Queensway	1" „ Colfix	33
Qutab Road	2½" Shelcrete	24
Karnal Road	1½" Armour coat with Tar/Bitumen	30
	Do. Colas . . . Do. Bitumuls . .	30 38
	Traffic census operations.	
Badli Road	Creteways	48
Return *viâ* Lawrence Road and Rohtak Road to Najafgarh Road, Mile 12.	Painting with Tar on Lawrence Road.	..
	Surface painting with Tar/Bitumen on painted Road Mile 6.	36
	Surface painting with Tar/Bitumen on Waterbound road Mile 11.	36
	Surface painting with Bitumuls in 1 furlong of Mile 12.	34

Route.	Nature of surface on road to be inspected.	Ref. to Paper No: 1A.
Return *via* Palam Road, New Cantt. Road Upper Ridge Road and *viâ* Tibbya College to Old Rohtak Road Miles 1 and 2.	Surface painting with Tar No. 2 and Chandigarh ballast.	..
	2½" Tar Carpet with seal coat applied after 2 months.	25
	2½" Shelcrete	24
	Mix-in-place treatment . . .	35
	Water Bound Tar Macadam . .	45
	Cement Concrete . . .	37
	8 ft. Cement Concrete and 16 ft. wide 2½" Tar Carpet and 2½" Shelcrete.	44
	2½" Tar Carpet with seal coat applied at once.	25
Return to New Delhi.		

Second day: Tuesday, December 11th, 1934.

The Congress re-assembled at 10 A.M. on the 11th December at the New Delhi Town Hall and proceeded on an inspection of roads according to the following itinerary :—

Route.	Nature of surface on road to be inspected.	Ref. to Paper No. 1A.
Leave New Delhi Town Hall *viâ* Parliament Street.	1" Carpet Shelsheet . . .	26
	1" ,, Hot Socony . . .	33
	1" ,, Tar No. 2 . . .	26
Great Place	1" ,, Tar No. 3 . .	27
Raisina Road	1" ,, Tar No. 2 . . .	26
Queensway	1" ,, Colfix	33
Qutab Road	2½" Shelcrete	24
Karnal Road	1½" Armour coat with Tar/ Bitumen.	30
	Do. Colas . . .	30
	Do. Bitumuls . .	28
	Traffic census operations.	
Badli Road	Creteways	48
Return *viâ* Lawrence Road and Rohtak Road to Najafgarh Road, mile 12.	Surface painting with Tar on Lawrence Road.	..
	Surface painting with Tar/Bitumen on painted Road, mile 6.	36
	Surface painting with Tar/ Bitumen on Water Bound Road, mile 11.	36
	Surface painting with Bitumuls in 1 furlong of mile 12.	34
Return *viâ* Palam Road, New Cantonment Road, Upper Ridge Road and Tibbya College to Old Rohtak Road, miles 1 and 2.	Surface painting with Tar No. 2 with Chandigarh ballast.	..
	2½" Tar Carpet with seal coat applied after 2 months.	25
	2½" Shelcrete	24
	Mix-in-place treatment . . .	35
	Water Bound Tar Macadam. .	45
	Cement Concrete	37
	8 ft. Cement concrete and 16 ft. wide 2½" Tar Carpet and 2½" Shelcrete.	44
	2½" Tar Carpet with seal coat applied at once.	25

Route.	Nature of surface on road to be inspected.	Ref. to Paper No. 1A.
Return to New Delhi Town Hall .	....	..
Leave New Delhi Town Hall *viâ* Welseley Road to Muttra Road, mile 7.	2½″ Shelcrete	24
	1″ Carpet with Ormul Emulsion .	34
	Stanotread treatment . . .	47
Return *viâ* Delhi Gate, Elgin Road, Jumna Bridge to Meerut Road, mile 4.	Tar Carpet } on Jumna Bridge. Shelcrete }	26 24
	Concrete Road	37
	2½″ Hot Socony Premix . .	46
	2″ Grouting with hot Asphalts .	22
	2½″ Shelcrete	24
	2½″ Trinimac	47
Return New Delhi.		

Second day, Tuesday, December 11th 1934 (contd.).

The Congress re-assembled at 2-30 P.M. with Mr. A. Brebner, C.I.E., in the Chair.

DISCUSSION OF PAPER No. 1A.

Chairman: Gentlemen. we propose to discuss to-day the papers which we have from Mr. Dean, Mr. Breadon, and Lt.-Col. Wakely. As I explained yesterday, we propose to take them as read and to devote the time to the discussion. We will first discuss Paper No. 1A and I will now ask Mr. Dean to say whether he has anything to add to what he has already told us.

Mr. A. W. H. Dean (the Author): No, Sir, nothing at all till after the discussion.

Chairman: I must say I have not much to say or add to what Mr. Dean has shown. I explained yesterday that the work we do here is partly for the Municipal Committee, partly for the roads which are under the Chief Commissioner and partly—and perhaps what is most interesting—work which we have done with money which we have got from Mr. Mitchell. I mention that because somebody said that we have not spent as wisely as we might have. I do not think any one can complain of what we have shown, at least in one respect. We seem to have seen different kinds of work. It was in fact, one might almost say, embarrassing. It is difficult to remember what we have seen and what we have not seen. In one respect I would criticise what Mr. Dean has shown us. I think there was a tendency to show us too much new work. What most people, I think, would like to have seen was old work and then would have decided whether it was likely to stand up to traffic or not. A great deal of what we saw was work which had been put up in the last month or two and naturally looked very nice indeed.

Mr. G. Reid Shaw: First of all, I should like to congratulate Mr. Dean on his very excellent paper and the great care he has taken in preparing it and also for his personally conducted tour. Having said that, I hope he will pardon me if I make a few criticisms, not only of his paper but of the majority of the papers that have been submitted to this Congress. In the first place, I think not enough attention has been paid to the difference in climate in the various parts of India. The papers on the Delhi and the North-West Frontier Province roads convey very little idea as to the climatic conditions and, in road surfacing work. the climate has a great effect on the various materials used and in the methods of using them. If the papers would give us the maximum and minimum temperatures and the rainfall, it would be a great help to us and would render the papers less parochial.

For comparing the prices of the work in different provinces, the prices of raw materials such as metal, chippings and sand and the labour costs ought to be given separately so that we can compare and estimate the cost of such work in different provinces.

I think also that not sufficient attention has been paid to failures. Most of us learn more from failures than from successes. I know we

have had one or two comparative failures in Assam. We will be only too glad to tell you about them at some other time. Unless we know what have been definite failures in one province or another, it is not much use only talking about successes.

Another point is that we lack the considered opinion of the Engineers who have laid these roads or who are responsible for them, as to which of the materials give the best results. It is rather difficult to form an opinion in a few hours' time. When these experiments have been carried on for a short or preferably a long time, it is essential to give the cost of maintenance in relation to the traffic intensities.

Mr. N. V. Modak: I must also join the previous speaker in congratulating Mr. Dean for his very interesting and instructive paper. Of course the things about which I am going to speak and the methods obtaining in the city of Bombay are quite different. The conditions obtaining in the city roads are different and the same conditions are not applicable to the country roads at all. In the city we have to deal with traffic which if measured would be 2,000 or 3,000 tons per yard width per day. I am now going to speak only about city roads. I have very little experience of district roads, but from what I can judge from the methods obtaining on the roads which we were shown to-day, I think I can say that we in Bombay are practically following the same methods in improving the city roads. It was in 1913 when the conditions of the roads in Bombay grew from bad to worse that several experiments were tried, first oiling the roads, then tarring with tar mixtures, but ultimately we found that they failed and that they did not give the required result. From 1913—20, we used something like 12,000 tons of tar on our roads. Of course the tar was obtained from the local gas works and it was too fluid for the work. Then we tried to mix tar with pitch and there also we failed and ultimately about 1920-21, we found that the results that we obtained were not at all satisfactory and that our cost of maintenance was going up. So we thought of using asphalt because asphalt was cheaper than tar. We also tried to use asphalt on the surface and still that method is in use. Out of 220 miles of roads in the City, 120 miles were treated with surface dressing with asphalt in the shape of 2 coat work. The first coat took 3 gallons per 100 square feet and four to five cubic feet of metal of 5/8 inch to 3/8 inch blue basalt chips. The second coat consisted of 2 gallons per 100 square feet covered on with 3 cubic feet of 1/8 inch grit mixed with 40 per cent. of dust. It was found that if pneumatic tyres were used in fast moving traffic, the road would last two to three years. That is our experience. If the foundations are bad, we must replace them with good ones. In the case of district roads, they have got the advantage that they are in existence for a number of years and with the periodic addition of metal in renewed coats, they get on to what you call solid foundations. The average comparative cost is Rs. 4 per 100 square feet for one coat work and the average cost for two coat work is Rs. 5-4-0 per 100 square feet. The natural surface dressing does not give additional strength to the road, but it is only intended to be a sort of road surface and when heavy traffic started going on the roads, we had to go in for what we call grouting penetration method and here we want to incorporate a sort of plastic binder material in the road itself. Before we decide on grouting, we try with one coat of painting suitable for roads from which steel tyred traffic is excluded.

I am referring to the Queen's Road in Bombay which is standing up very well with one coat of asphalt every year. It carries about 15,000 vehicles a day in 24 hours and at the time of peak loads, the traffic amounts to something like 1,200 vehicles per hour. When we started grouting, we only went in for grouting over such roads as had good foundations. Otherwise we provide concrete foundations. The penetration work was done in two coats and the total asphalt used varied from 1¾ to 2 gallons per square yard, the first coat taking 1¼ to 1⅓ gallons and the second cost ¼ to ⅓ gallons. Several roads have been laid by this method.

Mr. P. L. Bowers: May I know, Sir, if this is all a criticism of Mr. Dean's paper or if the speaker gives a description of Bombay roads?

Chairman: I hope Mr. Modak will realise that we might allow a certain amount of latitude if we had unlimited time at our disposal. Our time is short and we are supposed to be discussing Mr. Dean's paper and not the conditions in Bombay.

Mr Modak explained that he had made certain notes of experience in Bombay that he thought would be of interest to the Congress, but that if it was felt that they were too long to be read in the time available he would agree to their being incorporated in the proceedings as communicated. His communicated remarks follow:

Mr. Modak: To cut down the cost of this method where the traffic was not intense semi-grouting has been introduced.

The total asphalt used in this method varies from 1 to 1¼ gallon per square yard and the work is done in two coats.

There are about 15 miles of road laid by the two methods. These methods give thicker carpets and consequently fewer renewals. Asphalt with high penetration does not appear to be suitable; 40 to 60 penetration asphalt gives better results.

The next step was Hot mix plant work. In this method grading of the aggregate was possible and just sufficient asphalt could be used for uniformly coating the aggregate without any excess which is unavoidable in hand pouring work done in semi or full grouting. For very heavy traffic sheet asphalt has been used.

There are about 37 miles of sheet asphalt pavement which is laid in two layers, each 1½-inch in thickness. Municipality purchased a special plant to carry out this work. It is capable of laying 500 sq. yards of 3-inch work and 800 sq. yards of 2-inch work in working day of 10 hours. The hot mixture is taken to the site of work in lorries. The First sheet asphalt pavement on concrete foundations was laid in 1921-22. The cost at that time including foundations was about Rs. 17-5-0 per square yard. To-day it is about Rs. 7-8-0 per square yard.

It is estimated that this carpet will give an average life of about 15 years. The average cost of maintenance is found to be about two annas per square yard per annum. Where the traffic is not heavy, hot plant mixed macadam has been used. About 10 miles of roads have been laid by this method. It is similar to sheet asphalt as regards the binder course but the wearing course is only ½ inch instead of 1½ inches. The present cost of this work is about Rs. 2-12-0 per square yard. This pavement has given good results. No repairs had to be done to the roads treated by this method for the first five years.

'Cold Mix' work has also been done. It is laid in three different ways—

(1) Single course work 3 inches thick.

(2) Two-course work using chips for the top course.

(3) Two-course work using half chips and half sand for the top course.

Cold emulsions are only used for monsoon repairs. They are not found suitable for surface dressing.

On page 6 of his paper Mr. Dean states that the purpose of the experimental stretches of roads is to select materials and methods best suited to the needs of the traffic and to the financial resources available for the upkeep of the roads. Our aim is to establish an equilibrium between the needs of the traffic and our resources. The Bombay Corporation was in the same difficult position about 20 years ago. There was intolerable nuisance from dust. The motor traffic had considerably increased and the cost of maintaining the roads was annually increasing. The milage of city roads in 1911 was 161½ covering an area of 4·4 million square yards. The cost of maintaining these roads in that year was about Rs. 6 lakhs. In 1916, the milage increased to 172 covering an area of 4·0 million square yards. The cost of maintaining the roads in that year was more than doubled. Several expedients were tried to keep down the cost of maintenance but they were found to be unsuccessful. The cost of maintenance continued to increase. In the year 1922-23, it was as high as 33·46 lakhs. It would have gone up still higher. The obvious remedy to keep down the cost was to build up substantial roads from borrowings, if it was economical in the long run to do so. Borrowing helps to distribute the initial cost equitably over the present as well as the future rate payer. The principle of borrowing is that if a particular form of construction required an outlay which could not be met out of revenue owing to its heavy initial cost, borrowing would be justified provided there was sufficient margin on the current expenditure to meet not only the interest and sinking fund contribution on the debt but also upkeep and renewal of the road during the currency of the loan if such renewal was necessary. Thus, if the water bound macadam costs say one rupee per square yard to maintain annually then its replacement by a more expensive method was justified if the interest on its initial expenditure at 6 per cent sinking fund at 4 per cent, the expense of annual upkeep and the proportionate cost of renewal, if such a renewal was found necessary during the currency of the loan, did not exceed that rate of expenditure annually. After going into this question it was found economical to resort to permanent road construction by borrowing. The loan period was fixed at 30 years, the rate of interest was 6 per cent, and the sinking fund contribution was fixed at 4 per cent, compound interest. In working out the financial forecast of every road treated under the capital road programme the following important points were given special attention.

(1) The form of construction to be adopted. (2) Its initial cost (3) its probable life. (4) Average maintenance cost per annum

By adopting the principle of borrowing, it has been possible to save considerably on the maintenance cost of the roads in the city. The milage today stands at about 222. The important arteries of the city and principal roads leading to business centres have been treated with permanent mode of construction at a cost of about one crore of rupees. In 1922-23, *i.e.*, before the introduction of the capital road programme, the cost of maintenance amounted to 34·85 lakhs including Rs 1·77 for street watering and 1.38 for removing the mud from the roads in the monsoon In 1931-32 the cost of maintenance amounted to about Rs. 12·16 lakhs and about 10 5 lakhs for debt charges giving a total of about Rs. 22·66 against the figure of Rs. 33.46 lakhs budgetted for in the year 1922-23.

Mr. O. H. Teulon: I should like to associate myself with the previous speakers in thanking Mr. Dean for his valuable paper. There is really only one remark which I have to make. Mr. Dean refers in his paper (page 22) to grouting with hot asphalts and on pages 45 and 46 to "water bound tar macadam". It seems to me that both these methods are very unscientific methods of road construction and that if this Congress condemns these methods, we will at least achieve something. Both these methods represent a sort of happy-go-lucky style of engineering and when you have the opportunity of mixing your materials together in a scientific manner in a Millars' mixing machine or any other mixing machine, it seems a pity to do any more grouting or water-bound tar macadam coat work (Applause).

Diwan Bahadur N. N. Ayyangar: We saw a large number of different kinds of roads this morning and most of them seem to be very suitable within municipal limits. Most of us Engineers here are connected with

problems of rural roads in the districts outside municipal areas wherein we have got both bullock carts traffic as well as motor bus traffic. So really our problem is to find a road which serves the dual purpose both for bullock carts as well as for the motor bus or lorry service. From what we saw to-day and yesterday, I do not think we are in a position definitely to say which of the roads would serve this dual purpose and from the experience that we have of the district roads where both kinds of traffic exist, it seems to me that surface painting would not serve that purpose at all. From my experience in Mysore and also Bombay, I can say that that kind of work would not stand the bullock cart traffic where the rims are narrow and iron shod. The only thing that would stand that kind of traffic would be the pre-mix type or grouting and semi-grouting. Even they sometimes do not stand the cutting action of bullock carts. From our experience of the Bombay-Bandra road where both kinds of traffic exist, and the work is of purely grouted type the life of the roads has been about 5 or 6 years. When the side portions used by bullock carts got damaged these portions have been repaired by new patch work and the road is likely to stand for some years more. One thing, in the maintenance of these asphalt roads, seems to me to be that after we make these roads, we leave them unattended until they are damaged by wear. I think this is a mistake. They ought to be renovated periodically and after say, two or three years. Maintenance and repairs should be done continuously. If that is done, the surface keeps up just the right kind of quality of bitumen and the life of the road would be prolonged immensely. The cost of maintenance would be 2 to 2½ annas per square yard. That has been the experience on the Bombay-Bandra road. While talking of the dual purpose road, I think our ordinary macadam has been able to stand the ordinary bullock cart traffic but not these asphalt surfaces. The cement concrete seems to stand that purpose better. On page 49 of Mr. Dean's paper, it is said:—

> "Types of construction—Bharatpur stone slabs: These slabs are 4 inches thick and 8 to 10 feet long and have been laid on the ordinary soil. The clear space between them was 3 feet."

I wish to know what the kind of stone used there is, whether it is soft sand stone, or gneiss. If we know the kind of stone used, that would solve the problem to a very great extent indeed. If the stone is hard and is of good wearing quality, then all the buses and motors can go in the centre.

(The speaker explained his point to the Congress by means of a diagram on the black board.)

In Bangalore we have not gneiss and granite and we get splendid slabs 8 to 10 feet long, 2 feet wide and 3 to 4 inches in thickness. That kind of work has been laid near Bangalore and I find that you can travel at 40 miles on that road. I think that kind of surface is far superior to the concrete for various reasons. For bullock carts the stone is too hard and as soon as bullock carts go on to that surface, they swerve to the sides and use the portions of the macadam surface. The motors can use the centre of the road with slab ways. The damage to the remaining portion of the road surface is thus obviated.

About tar I can tell you that I was very shy about it because the Bandra-Ghodbander road was the first thing that was done in the Bombay Presidency with a tar carpet. It was done in two coats. After three or four years I went there again and I was shocked to find that we could not drive over the road at all with any speed. The result was that the whole tar carpet had to be ripped open; and that is why I tell you I was shy about tar. But I have now seen so much of the work in tar done in the Punjab and the North-West Frontier Province. I do not however know whether it would stand bullock carts. It is a great problem and that is the reason why we want a dual purpose surface.

I wish to say this much about these trackways. I also wish to know what kind of stone is being used in Bharatpur and what the experience has been.

Mr. K. G. Mitchell: I think one of the things which this Congress may bring about is the standardisation of certain specifications, and concentration on certain definite things which have proved to be good to the exclusion of those which have proved to be bad. I was personally responsible for some of the number of things which you have seen. There are certain specifications which have been introduced recently and in future years when we give you a report about these various things it will perhaps help that you have seen them and know a little more about them than if you had not.

As regards what Diwan Bahadur Ayyangar said about trackways, certain of these had been laid in Bharatpur State in stone slabs of the ordinary hard Agra sandstone.

Diwan Bahadur Ayyangar: It is too soft.

Mr. K. G. Mitchell: The tracks have been there for three or four years and I do not think any of the slabs have either cracked or worn out badly.

Diwan Bahadur Ayyangar: How are they laid?

Mr. K. G. Mitchell: They have been laid on a bad kutcha road. They were used in the first instance for crossing the Bangunga river. They were laid on the sandy bed of the river and they were taken out during the monsoon when they would have been lost and anyway the sand is moist and bad. Subsequently they were laid in continuation on a bad earth road with extremely sandy soil and the traffic such as it has is entirely concentrated on the tracks which have been of great value.

Mr. S. S. Bhagat: I must congratulate Mr. Dean on the great pains he has taken in preparing this paper. But I must say that the paper as it is written is not very helpful to those who have to construct the roads as we are not told why the different specifications which we saw this morning were tried,—whether they were put down with reference to the traffic with which they have to cope or whether they were put down haphazardly as funds permitted. It would also have been very helpful if dates had been given when the different specifications were put down on the roads so that we could see how long they have been under actual working conditions, because to compare the different surfaces it is always essential to know how much traffic there is and how long the different specifications will stand up to that traffic. Without these data a comparison cannot be made very easily.

Mr. D. Macfarlane: I want to make a remark about one subject to which reference has just been made, that is to say, the trackways. We were told about the stone setts that were laid on a kutcha road. Of course they have a very great use in solving the problem of cheap construction of roads, but I should like to quote my own experience of a certain canal bank in the Punjab. The canal banks, as you may know, are most excellently maintained and you can travel at a very high speed. But on the Lower Bari Doab canal between Balloki and Renala, the canal bank is full of saltpetre and with a view to enabling people to get along them they had trackways of brick, each about 1½ feet wide. The first thing that I noticed about these trackways was a big notice saying, "Speed limited to 15 miles an hour." This rather surprised me but I found out the reason in a very short time. I was doing about 25 miles an hour and it was excellent going but very shortly afterwards I found that I was swaying off the track and my back wheels got into the soft dirt on the side of the road and I skidded badly and very nearly landed into the canal. That, I could see, was the real reason why we were warned not to go beyond 15 miles an hour. A few days before the Roads Congress I saw the trackways at Jharanwala. I tried the same thing there with the same result. I think most motorists will find that it is a real strain after a short time to keep the wheels of the car on the trackway and not to sway. This is not a criticism that I make with a view to shewing that trackways should not be built, but to show that they introduce an element of danger to high speed motor traffic.

Colonel G. E. Sopwith: There was a remark in Mr. Dean's paper this morning which I noticed rather prominently and which Diwan Bahadur Ayyangar has dotted the i's of and also Mr. Modak, to the effect that tar painting will not carry heavy traffic and specially bullock cart traffic. Most of the delegates have seen a considerable proportion of the roads in the Punjab and also in the Peshawar district. They would recollect that the traffic between Nowshera and Peshawar is 350 tons per yard width a day upwards, and remember that the whole of that with the exception of about 5 miles is only tar painting; and I think the condition of the road speaks for itself and I am glad to hear that Diwan Bahadur Ayyangar is going to try it again. I do not know what tar Diwan Bahadur Ayyangar was referring to because all experience goes to prove that it is very difficult to produce road tar from gas works crude tar.

The only other point that I should like to emphasise is about the tar bitumen mixture experiments. The experiments which you saw this morning and which have only just been laid down have been done to the specification and laid under the supervision of the technical staff of Messrs. Burmah Shell and Messrs. Shalimar Tar Products jointly. As they are both as ignorant as any one else of what the result is going to be and whether the mixture is going to prove an advantage over the straight product it will probably take a very considerable time before they will be able to pass any judgment on it. As regards the tar-bitumuls mixture experiments, prior knowledge of this was not possessed by the company which I represent and we did not therefore advise on that. This is in no way a criticism of the specification or the method by which it was laid.

Chairman: I will now call upon Mr. Dean to reply to the points raised.

Mr. A. W. H. Dean (the Author): Mr. Chairman and gentlemen, before dealing with the points that have been raised just now I have a note which was sent in by Mr. Hunter (U. P.) with regard to some of the points which have been raised in the note and in the verbal introduction, which I will read out first. He says:—

> "The author states that on the length of road from Lothian Bridge to Delhi Gate, T. R. A. paint lasted for five years, and, a little later on, states that bullock cart traffic was too much for some of the six lakhs of square feet of such a surface that now exists. Am I to understand that the road first referred to, as lasting five years, is not subject to this kind of traffic?"

Actually that is the case. There is a side road for most of the length of that road to which bullock carts are confined, and for the remainder, bullock cart traffic is very light.

I am asked further:—

> "Is Mr. Dean in a position to give a figure indicating the weight of bullock cart traffic, per foot width of road, that he considers a bitumen treated surface should be able to stand up to satisfactorily? In answering this question I would like him to allow for the fact that, on some wide roads, the mean intensity does not represent that on the actual portion used by the bullock carts."

I have not any very definite figures to give. In any case the figures that we are working out, as is I believe the usual practice, are based on the per yard width of the road and to take into consideration the whole width of the road available. It is, I think, obvious that if you start to take only the track on which you say bullock carts travel, you can take any figure to represent almost any traffic load you like. I can quite imagine people reducing it to the width of the tread for instance. We must take the full width of the road available, and my experience is that unless we have some definite hold on the traffic, they tend to wander extensively over the whole of the road that is available for them. The figures as to traffic census which is in progress will be available, I hope, in about six months' time in the form of a paper probably published in "Indian Roads".

Then the point that has been raised by, not one, but by three or four, is this:—

> "It is stated that surface painting with tar has been found suitable for light traffic only. Was the tar allowed to become brittle or was it kept alive by repeated applications?"

My point was not essentially that it was surface painting with tar only that was found suitable for light traffic, but that any surface

painting was suitable for comparatively light traffic only. The point is this: you have to consider the economic rate of renewal. In the Punjab we have seen roads carrying fairly heavy traffic—although lighter than that on many Delhi roads which we have actually censussed—and the renewal period is every year or eighteen months. What we are looking for, for that type of traffic, is something that would last for something like three or four years at an increasing cost that is not going to exceed the cost of more frequent renewals with a cheaper material with the advantage of not having to interrupt traffic so frequently every year for renewals.

The last point that has been raised is this:

> "Can the author give us any idea of the relative satisfaction obtained from the various surfaces he has described?"

The point made by Mr. Brebner in introducing the paper, that most of the surfaces described are new surfaces explains why we cannot give you any figures of their economic life that are of any use at all. Mr. K. G. Mitchell has really replied to Mr. Brebner's criticism of the description and exhibition of new classes of surfaces. The point is that we wanted to show the latest and most up-to-date specifications; and actually those have only just been brought out and put into practice. It is the intention to get out a report on these and it is intended to give with that report details of traffic and maintenance that they had required. It was not intended to run them to destruction but to keep them up, judging by the expenditure necessary on maintenance the relative amount of wear that they have suffered.

With that, I think it would be very suitable to include some notes on the local climate. That is a factor that has been completely omitted; although one realises that climate does come into the picture and the difficulties experienced in practice in some seasons of the year and the changes which one has to make when one is doing work in certain seasons as against other seasons. A comparison of climates over various provinces of India had not entered my mind when I was writing the paper.

Then, the question of mentioning failures was also brought up. We have mentioned failures to some extent; but there is a very serious difficulty in mentioning failures· and that is that the reason for the failure is not always very clear, and when it is clear sometimes, it is possible the reason is local or climatic or something of that sort. A length of road may be laid after heavy rain and give rather different results, or in the very hottest weather in May; or there may be a slight discrepancy in following the specification laid down, particularly when supervision is not so easy; and things of that sort give rise to what appear to be comparative failures, and it is not always possible to determine that. I think merely to mention that a certain material was used or that a certain specification was followed and not found satisfactory without attempting to analyse the reasons for it would not be fair or reasonable.

We have been asked by several people the amount of satisfaction we have obtained from various surfaces. It seems to me that life in relation to cost is the criterion of usefulness. I am not going to lay-

down anything that is to be taken as a considered opinion of the Central Public Works Department. But I think you can classify our surfaces into three grades as being useful for light, medium heavy and very heavy traffic. For the first I think painting—according to a specification which we have put down but have not yet a final report on—with a high penetration tar followed by bitumen after two months, is satisfactory with traffic running up to perhaps 200 tons per yard per 24 hours. When I say that I do not mean it to be understood as bullock cart traffic, but general traffic: if it was bullock cart traffic alone, it would have to be divided roughtly by three or four to get the equivalent rate. Then we come to the pre-mixed carpet. Here I may say that I agree definitely that the grouting and water bound mixing are not so scientific and in effect not so satisfactory as a pre-mixed carpet. You cannot control the proportions nearly as well and you get patchy appearances which nearly always mean patchy wear and an unsatisfactory road. It will probably carry up to about 800 tons per yard if you have a satisfactory pre-mixed carpet of bituminous concrete and in that I think a very definite grading of your aggregate, the maximum size of which should be less than the thickness of the carpet, graded down to sand, is a better bituminous carpet than one using approximately one size of aggregate and not so completely graded. For still greater intensities of traffic a 7-5-7 cement concrete road will carry, as far as we can see, the heaviest traffic both bullock cart and motor.

Diwan Bahadur Ayyangar has made a point about dual purpose roads. All our roads are likely to be so except a certain number in cantonments and civil stations where we can keep the bullock cart off; and there the painted surface seems to be giving entire satisfaction. He also mentioned 7 to 10 years life and was rather critical of materials which had failed to stand up to that . . .

Diwan Bahadur N. N. Ayyangar: It will be more than ten years. Ten years is the experience; I think it will be more, certainly.

Mr. A. W. H. Dean (the Author): We have not yet found anything that would give the roads in Delhi a life of ten years, unattended. As regards the Bharatpur stone and the question of trackways, speaking subject to correction, I think the theory was that bullock cart traffic would use the trackways and motor cars would use the earth road . . . .

Diwan Bahadur N. N. Ayyangar: Our conditions are opposite.

Mr. A. W. H. Dean (the Author): Mr. Bhagat wanted to know the reasons for deciding in favour of the various surfaces we put down. They were selected according to our judgment of the necessities of traffic and as funds permitted and that I think is all we can say: we have not yet actually completed a census so we had very little to guide us in assessing the exact traffic load coming on to the roads; but it is in progress now and will help us materially. The paper has also been criticised for not having given the dates the various types of surfaces were put down. As far as I remember the year and month of laying down the surfaces have been given.

Mr. Macfarlane's remarks on speed on trackways is covered by my reply: our desire is to get bullock cart on the trackway and the motor cars on the earth road.

I have already covered Colonel Sopwith's observations in my remarks about tar painting. My personal experience is that no paint will carry heavy mixed traffic at an economic rate of renewal. I cannot really feel that painting every twelve months is really as satisfactory as putting down a better class of surface which would give a longer life. I quite admit that we have not a great deal to go on now; but the mere interruption to traffic entailed by painting must be a source of inconvenience if it extends over several thousand miles of surfaced road in a province every year or eighteen months.

Colonel G. E. Sopwith: May I say that I have particularly mentioned the Peshawar district because there we paint every two or three years and we hope yet to persuade the Punjab to adopt the same principle: I am sure then that their costs will go down.

Mr. A. W. H. Dean (the Author): There is one other thing: it has been pointed out that in the paper I gave, under the head of Trinimac (page 27) it is stated that five pounds of asphalt cement per cubic foot of stone aggregate was used for the first course and a similar quantity for the second course. Actually the rate was 4·8 pounds in the first course and 6·8 pounds in the second—a rather material difference which I am afraid was not before me when the paper went to press.

The Chairman then proposed a vote of thanks to Mr. Dean, which was carried with acclamation.

The following information was supplied by Mr. A. W. H. Dean (the Author) and circulated to members of the Indian Roads Congress :—

DELHI.

Rates for Materials [per 100 c f. at dump].

	Rs	AS.	P.
1½-inch Quartzite Road metal	6	0	0
Badarpur sand	8	8	0
¾ inch Quartzite Ballast	15	0	0
⅜ inch stone grit	18	0	0

Cost of Carting [per 100 c. ft.].

	Rs	AS.	P.
Up to ½ mile	2	8	0
1 mile	3	0	0
1½ mile	3	8	0
2 miles	4	8	0
3 miles	5	8	0

For each additional mile add Re. 1 per 100 c.ft.

Rates for other Materials [per ton F.O.R. Delhi.]

	Rs.	As.	P.
Colado emulsified bitumen	150	0	0
Colfix	150	0	0
Bitumuls HX, WX and FX	150	0	0
Bitumuls HRM and XRM	154	0	0
Socony Emulsion No. 6	175	0	0
" " No. 3	150	0	0
Colas	150	0	0
Socony Asphalt grade 101	133	0	0
" " " 105	133	0	0
Spramex (80—100)	133	0	0
Mexphalte	133	0	0
Shelmac	133	0	0
Road oil F. 70	133	0	0
Road Tar No. 1	120	0	0
" " No. 2	140	0	0
Shalimar Tar No. 2	117	0	0
Bengal Chemical Tar No. 2	115	8	0
Road Tar No. 3 Shalimar	117	0	0
Bengal Chemical Tar No. 3	110	8	0
Cement	40	8	0

Chairman: I will now ask Colonel Wakely to introduce his Paper. I am not aware whether he wishes to make additional remarks, but if he wants to do so, he may do so now.

The following paper was then submitted for discussion:—

(*Paper No. 4.*)

Earth Road Development and Stabilisation with Gravel *

by

Lieut.-Colonel A. V. T. Wakely, D.S.O., M.C., R.E.

1. *Earth Road Development Schemes.*—A fully metalled and surface treated road is the ideal construction for all main roads in India. There are many reasons why it is not possible to construct to this specification or to any other high class specification all roads that are required by the country generally. The chief reasons are financial, on account of the high capital cost of construction and the high maintenance charges for pukka roads.

2. Consequently by far the greatest mileage in India of any type of road is what is known as an earth road. This type has several great advantages—

(*i*) Low initial cost.

(*ii*) Low maintenance cost.

(*iii*) They are good enough for ordinary country traffic.

3. Earth roads as constructed in most places in India have many serious disadvantages—

(*i*) They receive little attention in the matter of maintenance, and consequently are allowed to fall into disrepair.

(*ii*) They are usually extremely badly built in the first instance, and on this account they are particularly liable to flood damage.

(*iii*) They are usually insufficiently provided with culverts and bridges.

(*iv*) They are not always constructed on the alignment best suited to serve the District through which they run.

4. Any scheme for earth road development, if it is undertaken at all, should be carefully designed so that the best use is made of the advantages of earth roads, and so that the disadvantages of them are reduced to the minimum or eliminated altogether. Earth roads are not, and never will be, as good as fully metalled roads, but there are immense possibilities in properly and carefully thought out schemes for their development. The main object of these

* Colonel Wakely's Paper originally contained two parts: (*a*) on earth road and (*b*) on the stabilisation of earth roads with gravel. The latter subject is however fully dealt with in his larger paper, "Road Construction and Maintenance in India" (Engineer-in-Chief's Technical Paper No. 10). Part (*a*) only of this paper is being printed but should be read with the notes on the other in the larger paper. The section in the larger paper dealing with "Gravel Roads" is reproduced at the end of paper No. 4. Both parts will be introduced by Colonel Wakely and be open for discussion.

roads is to act as feeders both to the railways and to the main roads. Their function is to carry agricultural produce to railheads and markets quickly, efficiently, and without undue hardship to pack and draught animals, and without damage and delay to mechanical transport.

5. The first thing to consider in making out any earth road development scheme is to find out what produce and what traffic each road is likely to carry when constructed. Each particular road, whether it be the reconstruction of an old road or the construction of a new road on a new alignment, should show a definite saving in transport costs on the existing arrangements. If such a saving cannot be shown the inclusion of the work in a road development scheme is not justified. These savings accrue in three ways :—

(*i*) By reducing the distance from the source to markets or railheads.

(*ii*) By eliminating delay to traffic by the provision of proper bridges.

(*iii*) By improving the surface so that wheeled transport can be used.

6. The usual rate for pack transport on an unmetalled unbridged road is 6 pies per maund per mile, while for wheeled transport on an improved and bridged unmetalled road it is 3 pies per maund per mile. By improving and bridging it is therefore possible to effect a 50 per cent. saving in transport charges. Within this limit various degrees of saving can be effected by treating the road in different ways.

7. It is usually possible to justify the improvement of any path into a road under one or other of the above heads, but in these days of financial stringency a very good case must be made out for the inclusion of any project in a scheme of earth road development. The intensity of the traffic can normally be taken as the guiding principle. It is suggested that the absolute minimum for which a road should be built or improved is 100 vehicles per day. The greater the traffic on any road the more justification is there for its inclusion in the scheme. It will probably pay to metal any road that carries over 500 vehicles a day. The earth road therefore finds its limits between 100 and 500 vehicles per day. The great importance of earth road development in India will be realised from the fact that about 90 per cent. of the total road mileage in India carries traffic between these limits. In any road scheme it is a question of rendering the greatest service to the greatest number of people at the least cost, and it is suggested that it is more important for the good of the country generally to develop these subsidiary feeder roads in a proper manner than to spend large sums on ambitious and luxurious main road schemes.

8. To turn now to the disadvantage of earth roads in the matter of bridges noted above. The thing that stops wheeled transport being used at all on an earth road in an irrigated area is the fact that there are numerous unbridged streams and irrigation channels to be crossed. This limits traffic to pack animals and raises the cost of transporting produce to market. Pukka bridges should be provided over all perennial streams and culverts for all irrigation channels. Causeways will do for *nullahs* liable to flood, since floods are of only a few hours' duration and that amount of delay to traffic is of no consequence. What is of consequence is that, if there is no causeway, the flood

tears up the road and several days work is necessary before wheeled traffic can cross at all. With many such places in a District maintenance costs run high, and it is not possible quickly to restore communication immediately after the flood.

9. *Estimates and Specifications for Earth Road Schemes.*—In any earth road development scheme it is suggested that the provision of pukka bridges should be one of the first considerations, and that every unmetalled road that justities improvement on account of its situation and traffic should *ipso facto* be either fully bridged or sufficiently bridged that traffic will only be delayed for a few hours during actual floods. It would be wearisome to detail all the instances and the causes thereof where bad construction in the past has rendered many unmetalled roads practically useless for the purpose for which they were built. Apart from the question of bridges, the causes fall under three main heads: (*i*) Width, (*ii*) Grade and (*iii*) Drainage. If these three items are properly attended to during construction the road, no matter what the surface may be, will be a good road. If economy is attempted on these three items the road will be a bad one, and will remain bad. It will also be a costly road to maintain.

10. First as regards width, the minimum should be 20 feet clear between ditch, and 30 feet should be given wherever possible. On a narrower road than this bullock carts find difficulty in passing and slide off the surface into the ditch. On a narrow road also traffic tends to track in the centre, forming ruts. On a wide road traffic distributes itself and uses the whole width and the evil of tracking is largely eliminated.

11. A steeper grade than 1 in 15 is too much for bullocks even for very short distances. It is better to aim at 1 in 20. Particular attention should be paid to the approaches to and exits from *nullahs*, and these should not be too steep. It is a mistake to suppose that short steep grades are allowable because modern lorries and cars can negotiate them with ease. It is the bullock cart that should be considered.

12. Many failures in road construction work are due to the lack of proper drainage of the subgrade. The only difference in the effect of poor drainage with different road surface types is a delayed action upon the high type surfaces. On earth or gravel roads bad drainage is immediately apparent, while on a premix tar or asphalt macadam type the effect is delayed, but in the end it achieves the destruction of the road. The rapid effect of bad drainage often creates the impression that an expensive type of road is necessary. Careful attention to the drainage in such cases would save large sums of money. The provision of good drainage is cheap, except in solid rock, and good drainage with an inferior surface would be adequate. for many roads in India the maintenance of which at a high standard is quite unjustified.

13. The first essential, therefore, in preparing a subgrade is to ensure adequate drainage from one end of the road to the other. A subgrade is not properly drained until it has been made impossible for any rain water to remain upon it, and impossible for any surface or irrigation water to flow on to it unless it is desirable to be able to flood the berms in order to increase the moisture content. It should also be made impossible for any water to remain

stagnant in the road side drains and gain admission to the road surface by capillary attraction. The water must be given a means of getting away to the natural drainage of the country. In order to do this it is necessary to grade the drains so as to ensure that there is sufficient fall in the drain. As a general rule a minimum slope of 1 in 100 should be given. Culverts or scuppers must be provided to allow the water to pass from the up hill side of the road without flowing across the road.

14. The number of cross culverts varies with the rainfall and the gradient. The principle is that surface water should be taken away from the road surface and road side before it has time to saturate the subgrade from the side drains. A fair average distance apart from culverts is about 400 feet or an average of twelve culverts or so per mile. While the foregoing is true for normal subgrades the moisture content in the soil should not be forgotten. Cases may occur where, in order to maintain the moisture content in the soil by capillary attraction it is advisable actually to arrange for water to remain in the side drains. Soils with a great excess of sand would be an example.

15. The object of good drainage is so to arrange matters that the moisture content of the soil will undergo as little change as possible and will remain fairly constant in dry weather till a fresh supply of water renews it. The subgrade must never be allowed to get saturated. In India many roads are constructed without any regard to the final roadway level. If the final level is set two to four feet above the surrounding country and the fill obtained from wide ditches on either side a lowering of the ground water level in respect of the roadway level will result. It also permits the run-off of heavy rainfall without injury to the road surface. The result is a stable condition of the subgrade or surface. Such surfaces appear to be of an entirely different material from that in the fields alongside the road. (*See* Figs. 1 and 2 at the end of this paper).

16. Another most important point in regard to good drainage is to ensure that the flow of water in the drain is not obstructed. An obstruction may be caused by a projecting rock in the drain, by a tree or by zamindars filling in the drain to give access to their fields from the road. In the latter case katcha bridges should be provided, or if there is a side lane a proper culvert should be built. A frequent source of obstruction is an irrigation drain running at right angles to the road side drain at a higher level. These must be provided with pipes or culverts. (*See* Figs. 3 and 4).

17. In road construction in India in the past it has frequently been the case that funds for construction have been limited. Savings have been made by omitting culverts and small bridges, or in other words by taking a chance in the matter of the proper drainage of the road. This has in many cases left a legacy behind which is reflected in excessively high maintenance charges especially for hill roads and roads that are subject to floods and spates.

18. It has been found in actual practice that very great savings can be made in maintenance charges if improvements in the drainage of the road are carried out systematically and thoroughly. Each road must be considered on its merits and a detailed reconnaissance should be made under flood conditions to find out exactly how and where drainage is deficient. New and large

culverts, more small bridges, catch water drains, cutting back ground liable to land slides and the provision of retaining walls are some of the methods by which maintenance charges can be greatly reduced.

19. The above three items, width, grade and drainage together with the provision for bridges constitute the main items on which the estimates for earth roads should be based. If a certain sum of money only is available it is far better to reduce the mileage of earth roads to be constructed or improved and to provide properly for the above four items than to cut down on these with the object of increasing the mileage and including additional roads in the scheme.

20. *Preparation of the Subgrade of an Earth Road.*—Coming now to the preliminary preparation for actual construction, the proper consideration of the subgrade is of vital importance. In India generally there are four different kinds of subgrade. There are many variations and combinations of these, and many special kinds, such as kankar and moorum, but broadly speaking the following four categories will cover all :—

(*i*) Clay,

(*ii*) Sand or Silt,

(*iii*) Gravel on rock,

(*iv*) Shaley gravel.

For an earth road the subgrades that will normally be met with are clay, sand and silt.

21. Before preparing the subgrade it is essential to know what sort of soil is being dealt with, and for this purpose a soil analysis should be made. There are numerous and complicated laboratory tests which can be carried out on soils, but in India it is necessary to send samples of the soils to laboratories which are probably many hundreds of miles from the site of the work. This means delay, which cannot always be afforded. It will, however, usually be sufficient to make certain field tests to determine the suitability of the soil for road making purposes and to decide what treatment is required to make the soil suitable if it is not so naturally. These tests are described below.

22. The definition of the three materials which compose most soils are :—

Sand.—Consisting of particles larger than ·05 m.m. in diameter and which will pass through a ¼ inch sieve.

Silt.—Consisting of particles not larger than ·05 m.m. in diameter and not less than ·005 m.m. in diameter.

Clay.—Consisting of particles less than ·005 m.m. in diameter.

If these materials are present in the subgrade in the proper proportions their properties of internal friction, capillary attraction and cohesion react on each other in such a way that the subgrade is stabilised, *i.e.*, it does not break up easily under traffic nor form mud in wet weather, nor dust in dry weather, except in a minor degree.

23. In order to determine whether materials are present in any soil in the correct proportions it is necessary to—

(1) find out the proportions of each material in the soil,

(2) find out whether the particular material in the soil possesses the properties required of it.

For instance, a road soil that is 95% sand will not cohere, and a clay that does not possess the property of cohesion is useless as a road material and will do nothing but make dust.

24. There are four field tests which should be carried out to determine (1) and (2) above:—

TEST I. *To find out the proportion of sand in the soil.*—Take a sample of the soil (dry) and weigh it to any weight that is a multiple of ten, *e.g.*, 300 grs. or 10 tolas. Put it in a glass and fill with water. Agitate it and pour off the clay. Do this several times until nothing but sand remains in the glass. Dry the sand and weigh it. The result will give the percentage of sand in the soil. The remainder is clay and silt.

TEST II. *To determine the proportion of clay and silt.*—To do this accurately is a laboratory test unsuitable for use in the field. For practical purposes it is not necessary to determine the exact proportions. A very good estimate can, however, be obtained by two methods:—

(1) Observing the colour of the sample.

(2) Noting the settling properties of the samples.

Silt is generally darker in colour than clay and a sample that contains too high a percentage of silt will not have the characteristic brown colour of clay. Silt settles more rapidly than clay. If the sample is put into a glass and mixed with water and allowed to settle the clay will remain muddy while the silt will settle within a few seconds. A sample that clears very quickly has too much silt, and some clay should be added to it.

TEST III. *To test the suitability of sand.*—Place a sample of the sand in a vessel containing water and agitate the water until the sand is thoroughly in suspension. Then when the sand has been allowed to settle pour off the water slowly. If of good quality, the sand will not be carried out with the water, but will remain in the vessel until practically all the water has been drained off. A bad quality sand will not meet this test, and is not suitable for use on roads.

TEST IV. *To determine the quality of various clays by the slaking test.*—Make up several balls of the same size of the different clays, and dry them out.

Place them in water so that they are covered entirely. The balls which hold their shape longest after being placed in the water have the highest resistance to slaking, and that clay is to be preferred for use in the road. It is important in this test that, if various clays are being compared, the proportion of sand in each sample be the same. It should not exceed about 25 per cent.

Therefore if under Test I the proportion of sand is higher than 25 per cent. the sand should be removed before doing the slaking test. This can be done by washing out the sand from the sample. If the clay is of the slaking variety, *i.e.*, if the balls disintegrate almost as soon as they are put in the water the clay is a bad one, and should not be used on the road. Samples that contain too much silt will not show good non-slaking qualities they will break up at once in the water. Clay requires to be added to such samples.

25. Having thus discovered the proportions and properties of the various materials in the existing soil, similar tests should be carried out for any materials locally available that can easily be brought to the road and used on it. Besides sand or clay various aggregates may be available. These should be screened to find out their composition. It will later on be of great value to know the composition of any aggregate that may be used. The tests for this are very simple, and consist merely in finding out what percentage of the aggregate passes through the various sieves and screens. A sieve has square apertures and the mesh of the sieve is indicated by the number of divisions per inch length, *i.e.*, a 10 mesh sieve has 10 divisions per inch or 100 openings per square inch. A 200 mesh sieve will only pass dust through it. A screen is described by the diameter of the circular openings. Small sieves about 3 inches or 4 inches in diameter of the various sizes should be carried when field reconnaissance is being done. These are quite good enough for rapid field reconnaissance.

26. The next step is to decide whether any special treatment of the subgrade is necessary. Gravel and good clay subgrades will require no special treatment, but if the soil analysis indicates the presence of other materials in the wrong proportions, it is probable that treatment is required and it must be given. The best proportions of the materials for an earth road are :—

Sand.—70 to 85 per cent.

Silt.—10 to 20 per cent.

Clay.—5 to 10 per cent.

It will usually be sufficient to consider silt and clay together without separating them, and a soil that contains 70 per cent. sand and 30 per cent. silt and clay would be a very good one, provided that the silt is not too much. This can be observed from the colour test and the slaking test.

27. If an old road is being reconditioned the depth of the existing surface should be ascertained. If a new road is being made it should be decided what depth of treatment should be given according to probable traffic conditions. Normally 8 inches depth should be aimed at, but if time and money are short 4 inches will do, or even 2 inches. Knowing the thickness and knowing the

proportions of the materials present in the soil it is easy to calculate what the correct thickness of sand and clay should be. If the proportion on test on an old road being reconditioned was :—

Sand.— 33 per cent.

Clay.—66 per cent.

and if there had been heavy traffic there would probably be 1 foot of dust on the road. An estimate should be made of the thickness to which this would consolidate. It would probably be 3 inches, which means that in the old road there was 2 inches of clay and 1 inch of sand. The proportion required is—

Sand.—75 per cent.

Clay.—25 per cent.

By adding 5 inches of sand a proportion of 6 inches of sand and 2 inches of clay is obtained. This is the correct proportion. Supposing that it was found that the proportion of sand in the road was 90 per cent. then clay would be added, to reduce the proportion of sand. It is desirable, but not essential, that whatever is added should be mixed thoroughly with the existing road soil and not merely laid on. Water should be used to consolidate the mix.

28. The following are some mistakes usually made in reconditioning or making an earth road :—

(1) *Brushing off the dust, before spreading anything on the road.*—This is a mistake, because the dust, or in other words the clay, may be under Test IV found to be very good non-slaking clay. If it is slaking clay it is correct to brush it off.

(2) *Using large shingle.*—This is a mistake because, owing to the proportions of the road soil shingle of large size will never bind. If the shingle is graded to proper proportions it would be correct to use shingle.

(3) *Putting clay on the road for filling ruts.*—This is a mistake as the ruts form because there is too much clay. Sand should be added. But if on test a deficiency of clay is shown it would be correct to put clay on the road.

(4) *Using bad sand.*—Only sand that passes Test III should be used.

29. The earth work on an earth road may be done by hand, but it is much quicker and more efficient to do it with a road grader set. The grader crew with its full equipment moves along the road as constructed and camps at suitable sites *en route.* The whole work on the road, whether it is reconditioning a new one should be under the Sub-Divisional Officer with an Overseer in charge of all work. The Overseer will control both the manual labour work, any bridge construction work and the work of the grader crew. It is unsound to make the *Mistri* in charge of grader work control any other manual labour.

30. Whether machinery is used or not there are certain items of work that must be done by manual labour, and they are as follows :—

(a) Repairing or constructing bridges, culverts, causeways, etc., and improving the approaches to them.

(b) Filling all places liable to flood and where big holes and depressions occur.

(c) Blanketing with good earth or sand all stretches containing unsuitable soil.

(d) Removing jungle and other obstructions.

(e) Providing milestones, etc.

31. The essential difference between work done by machinery and manual labour lies in cambering and improving the surface, the latter involves obtaining earth from borrow pits whilst the former does not, and therein lies the main source of saving.

Functions of the different machines.

A road grader set consists of the following machinery :—

1 35 H. P. Diesel or Petrol Tractor.

1 Leaning Wheel Road Grader.

1 Revolving Scraper.

1 Scarifier.

1 Drag Broom.

1 Lorry and Trailer or 2 Lorries are attached for administrative purposes.

The machines are separate units. The power unit can be attached to any one of the others and works it separately. This set can do the following work :—

(i) Road formation including digging out ditches and dressing the surface to a proper finish.

(ii) Filling dips, filling approaches to bridges and culverts and raising low lying portions of the road.

(iii) Cutting mounds of earth, scraping off bumps and easing gradients.

In ordinary soil where there are no obstacles or where such obstacles as trees have been removed the Road Grader will do about 20,000 cubic feet of earth per day. The efficiency ratio, or the ratio between the cost of the same work by hand labour and the cost by machine has worked out in practice at 1·56 with a petrol tractor. With a Diesel tractor the same ratio would be about 2·0.

32. Where there are obstructions to the work of the grader such as roots of trees, large bumps of grass or larger holes and depressions the rate of progress is greatly reduced, and consequently the efficiency ratio. Generally speaking

the work of one grader set is equivalent to that of 220 men. It should be noted that the loss of one hour's work of the grader means a loss of about Rs. 7 at least. It therefore pays to organise the work so that the machine is never idle.

33. The revolving scraper is used for filling work on the approaches to bridges and culverts and for deep dips and depressions. Where earth can be obtained within 25 yards of the site its use is economical. The efficiency ratio works out at 1·21. Where earth has to be obtained from a distance greater than 25 yards the use of the scraper is uneconomical, and it is cheaper to do the work by hand labour. Nevertheless the work will be done more expeditiously by using the scraper.

The scarifier is seldom required on earth subgrades, but is very useful if hard gravel or conglomerate is encountered.

34. The success and the economical use of the road grader set depends on the following factors:—

(*i*) Type of work, *viz.*, cutting, filling, road formation.

(*ii*) Nature of soil.

(*iii*) Existence of any obstructions to the work of the machines.

(*iv*) Efficiency of workmen and crews.

(*v*) Organisation of the gangs assisting the plant.

(*vi*) Supervision.

35. The first three items have already been noted upon, but it cannot be too strongly emphasized that the clearer run and the longer stretches of clear run that can be given to the machines the more efficient will be their work. Consequently organization of the gangs plays a greatly enhanced part in the financial result of the operations. The following gangs have been found most suitable :—

(*a*) *Crew*—

1 Mistri.
1 Tractor Driver.
1 Grader Driver.
1 Cleaner.
2 Chowkidars.

The two drivers should be interchangeable, as the tractor driving is very hard work, and it is definitely of advantage if both men understand both machines.

(*b*) *Gang No. 1* (4 Coolies).—This gang should be permanently with the set. One cooly helps the grader man with adjustments. The Mistri in charge should train these coolies in odd jobs, *e.g.*, operating the traversing gear of the grader, fixing and unfixing the street plates of the tractor when the machines have to march to another camp, and operating the string of the revolving scraper, etc. Trained coolies render very valuable assistance in extricating the machines in a trained and skilful manner, when the latter get stuck in boggy ground. While the machines are at work, these coolies should clear the ditches and remove bumps of grass that get mixed up with excavated earth.

(c) *Gang No. 2.*—This is a temporary gang of 4 coolies working in advance of the machines. Their duty is removing stumps of trees and roots, clearing bushes, filling in large holes where tree stumps have been extracted and generally preparing the road in advance of the machinery so that the latter will have a clear run. This gang may be increased up to 20 men according to the amount of work involved.

36. The cost per mile of grader work will vary according to the nature of the soil and the amount of obstructions encountered by the machines. On a straight open road the rate is Rs. 240 per mile for the road formation, but it may be increased to Rs. 450 per mile under adverse circumstances. In estimating for the construction of a road the rate should be determined carefully for each particular road and each individual mile of the road, after a thorough examination of the conditions affecting the rate as noted above.

37. Generally speaking all earth roads have not only lost their camber, but the centre is very much lower than the sides through years of neglect. There is no outlet for the water, which soaks into and softens the soil, the surface is therefore readily spoiled even by the lightest traffic. It is not difficult to visualise what a road surface is like when cattle have walked over it while in a sodden state. The first object of road grading is, therefore, to restore the camber. Where the rainfall is light and most months of the year are dry, excessive earth filling may take a year or more to settle, and in the interval of settling the road is a quagmire in the rains and very dusty in dry weather. Past experience shows that the best results can be obtained with the minimum inconvenience to traffic by making two separate gradings at an interval of two months between each allowing traffic to consolidate each layer. Excellent results are obtained if the two gradings are done just before and during the rains. A third grading should be done with the Auto-Patrol.

38. Before grading operations commence the exact alignment should have been decided and marked out. It is much more economical if the grader crew can have a clear run for the machines. They should not deal with any stretch less than a mile in length. All obstructions, such as trees, should be removed before the grader is put on the road. Culverts and bridges should be completed before the grader starts, if it is possible to arrange the work accordingly. The first round of the grader should aim at completing the first layer of the road surface. If the road surface has to be raised more than 18 inches any fill above that height should be left for the second round and a third round given later. The first round usually requires eight or nine runs of the grader, or even up to twelve depending on the nature of the soil.

39. The finished road should present a hard compacted surface with sufficient camber to allow any rain falling upon it to drain rapidly to the side. The amount of camber will depend upon the nature of the soil. Generally speaking, light sandy soils which drain quickly can be left with less camber than heavy clays, which retain the water and become muddy and rutted unless well drained. The camber should not be greater than drainage requirements demand—ordinarily, the slope from the centre to the side of the road should be about half an inch per foot. Provision of camber is the final step in the grader-built road. The ditches alongside the road should have ample capacity

to carry off the surface water. They should be deep enough and wide enough to provide proper drainage, should have sufficient longitudinal slope to keep the water moving, but not so great a slope that the speed of movement of the water will be likely to erode the banks and damage the roadway. The side ditches should have outlets into the natural water courses at as frequent intervals as possible.

40. Wherever possible, there should be a very gradual slope from the roadway to the bottom of the ditch. This accomplishes three purposes:

(1) It puts the ditch far enough away from the roadway so that the water in the ditch will not seep under the road surface to soften the subgrade.

(2) It makes less hazard than a steep bank to vehicles forced off the main roadway.

(3) It reduces the cost of keeping the ditches free from weeds and soil.

The cost of grader-built roads is proportional to the number of trips required and the speed of operation. The nature of the soil handled and the dimensions of the road have a direct bearing on these factors. Improper planning of the cycle of operations or carelessness of the operators increases the number of trips and hence the cost of the road. Co-operation between the tractor driver and the grader operator is essential for efficiency, and both men should be trained in each operation.

41. A cut should never be made until it has been determined where finally to place the material obtained. Get the material with the lightest cuts that will develop the amount of fill required. Place it in its final position with the fewest number of operations. In cutting a ditch, first set the blade at the proper cutting angle and then shift the frame on the rear axle so that the rear wheel will follow the point of the blade in the bottom of the ditch. For working in wet soils or in heavy grass, sharper angles of the blade are required than when working in light loamy soils. A little experience on the part of the grader operator will soon indicate to him the angle at which the blade cuts best for the particular soil in which he is working.

42. On steep slopes the weight of the grader will tend to force it down the slope. In such cases the wheels should be leaned on the axles so that they run in approximately a vertical position. On flat work, where the cutting is at or near the point of the blade and where there is little or no pressure against the heel, the force tends toward rotating the grader. The rear wheels have a tendency to move in the direction of the delivery of the material excavated and the front wheels in the opposite direction. The wheels in each case should be leaned in the direction opposite to this rotation. Thus if material is delivered from right to left, any tendency for the front wheels to slide towards the right and the rear wheels towards the left can be counteracted by leaning the front wheels towards the left and the rear wheels towards the right. A little experience and proper attention to this feature will determine both the direction and the extent to which wheels should lean.

43. The diagrams (Fig. 5 at the end of this paper) show the operations of the grader at each run on both sides of the road, one run up and one down :—

(1) Blade set at 30° to the centre of the roadway, and a shallow cut taken. The earth is thrown up in a mound on the road. Before this run is made it is necessary either to mark out the line with pickets or spitlock it so as to give the crew a straight line to work on.

(2) A cut inside the first cut, and more earth is thrown up.

(3) The blade point is set straight down, and takes a deep cut into the subsoil. Much earth is thrown up.

(4) With the blade in cross wise position the earth is spread towards the centre of the road.

(5) A deep ditch is again cut.

(6) The earth thrown up by the previous run is moved to the centre of the road.

(7) The ditch is properly formed and more earth thrown up.

(8) The blade set cross wise moves the earth towards the centre of the road.

(9) The last run smooths the surface and finishes the road.

The specification for an earth road should in general be the same as regards ruling dimensions as a Class I or Class II road. It is preferable to give Class I width throughout, since the wider the road is, the easier it is to maintain. On a narrow earth road traffic tends to track in the middle and ruts rapidly form, whereas on a wide road the traffic tends to use the full width of the road.

44. The following exceptions should be made in the approved specifications in the case of earth roads :—

(*a*) As these roads will probably carry bullock carts the maximum gradient should be 1 in 15. A steeper gradient than this is too much for the bullocks.

(*b*) No super-elevation on curves need be given.

(*c*) Roadside drains should be as wide as possible.

(*d*) Length of culverts should be the full width of the road formation.

(*e*) Mile and furlong posts should be of 3″ × 3″ steel angles 4′ long set in concrete.

No warning signs need be provided.

45. *Maintenance of Earth Surfaces.*—Too much attention cannot be given to the maintenance of earth and stabilised earth roads. The whole tendency in India with regard to earth roads is to allow them to look after themselves. This is a most uneconomical thing to do, because an earth road will deteriorate very rapidly if it is not properly maintained. The maintenance required is not

of a very high order, nor is it at all costly. It is also extremely simple, but the point is that it must be done and done regularly. The maintenance charges of earth or stabilised earth roads should not exceed Rs. 150 per mile per annum. This sum, however, must be spent sufficiently otherwise the whole of work of construction is largely wasted. It is less expensive to keep an earth road in good condition than to renew it after it has been allowed to deteriorate through lack of care. Timeliness is an important factor in road maintenance. Whenever possible the roadway should be reshaped when the surface is moist but not wet. When in this condition the work can be done with greater ease and the loosened material will settle and compact more readily. It is not advisable to do work on earth roads in very dry and dusty weather.

46. When the road surface is allowed to become rutted, rain water will collect in the depressions making mud holes and weakening the foundations, whereas an earth road with a hard smooth surface will shed rainfall and will dry off rapidly. If it is possible to do so, it is preferable to keep heavy traffic off the road during heavy rain and for a few hours afterwards, until the road surface has dried.

47. The following are the chief points to be observed on this maintenance :—

(*i*) Ditches must be kept clear of obstructions and water must not be allowed to collect in them.

(*ii*) Camber of road must be maintained.

(*iii*) When ruts begin to form they must be smoothed out.

(*iv*) Irrigation water must not be allowed to flow over the road.

In addition to this certain special repairs may be necessary, such as the repair of culverts, etc., for which materials are required.

48. Also, it has been found by experience on these roads that the Zamindars do three things which cause damage :—

(*i*) In order to give access to the fields the roadside drains (which did not exist before) are filled with earth.

(*ii*) Irrigation bunds are built so that they encroach upon the road.

(*iii*) During construction it may not be apparent exactly where culverts for irrigation channels are required. If a culvert does not exist the Zamindar digs a channel across the road for his irrigation water.

It is the business of the maintenance gangs to prevent these occurrences and to put them right. To give access to fields katcha timber bridges are good enough, but they must be so constructed that the drain is kept clear. Irrigation channels and bunds are an encroachment and should not be allowed. The channel should be made by the Zamindar on his own land clear of the roadside drain. As regards new culverts it is only after experience of the road under traffic conditions that the full requirements can be decided. A few new culverts will be necessary on all roads after construction has been finished, and allowance for them should be made in maintenance estimates.

49. In order to carry out this maintenance there are three methods any one of which may be used for a combination of all three :—

(*i*) By Auto-Patrol.

(*ii*) By hand labour.

(*iii*) By wood road drag scraper (*See* Fig. 6 at the end of this paper).

It is uneconomical to do earth work by hand labour. Maintenance gangs should be reduced to a minimum and used only for digging out ditches, clearing slips, patrolling and inspecting the road. and directing the work of the Auto-Patrol and the road drags. The Auto-Patrol should go over each road twice yearly re-surfacing, making up camber and trimming ditches. It does the same work as the grader, but on a smaller scale on an already properly graded road and much more rapidly. The road drag scrapers are used for re-surfacing and smoothing ruts, but they cannot bring more earth from the ditches on to the road.

(*i*) *Auto-Patrol.*—Allowing for doing all earth roads in wet weather and much of the gravel road mileage in dry weather and allowing for holidays and repairs to the machine, it is estimated that the Auto-Patrol should work 200 days a year.

50. The number of rounds required to put a road into good condition with the Auto-Patrol depends entirely on the condition of the road in the first place, but 4 rounds should not normally be exceeded :

i.e.,— 1 round in bottom gear at 1·8 m. p. h.
1 round in 2nd bottom gear at 3·7 m. p. h.
2 rounds in 3rd bottom gear at 5·1 m. p. h.

This means that the machine will travel 15·7 miles in four hours, and the completed mileage per day should be about eight miles. It will be safe to take 5 miles as the daily average, allowing for delays, bad places, time off for meals, idle movement, etc. The Auto-Patrol is definitely a one man control machine, all adjustments to both blade and scarifier being carried out through 5 control levers. A staff of one mistri and one mistri cleaner should be allowed for it.

51. (*ii*) *Maintenance Gangs.*—A permanent working gang of 1 man per 4 miles should be sufficient. Each gang would consist of 1 mate and 4 men and would have charge of 20 miles of road. Mates might be provided with a bicycle Maintenance gangs should be provided with the necessary tools and equipment.

52. (*iii*) *Drag Scraper.*—The drag scraper is a locally made article costing about Rs. 50 each. Each maintenance gang should have 2 drag scrapers as part of their equipment. These scrapers should be centrally situated and kept in a suitable village on the road. Each one can maintain 10 miles of road without undue travelling to and from work. The scraper is pulled by two bullocks. In using scrapers it is important to remember two things :—

(*a*) It is difficult to train the bullocks to pull the scrapers properly, as they are at first unaccustomed to this kind of work.

(*b*) It is therefore difficult to persuade the gangs to make proper use of the scrapers.

53. The scraper can be so inclined that earth can be drawn to the centre of the road or away from the centre or else merely smoothed as in Figure 7 at the end of this paper. Thus for a road requiring extra camber the scraper should be inclined with its left leading edge in advance. If the camber is too great then the right leading edge should be in advance. If a smoothing action only is required then the scraper should be drawn at right angles across the road. The amount of cut that is made can be varied by adding extra weight in the way of sandbags filled with earth or stones on to the top of the scraper or by the cooly standing on it, but it should be remembered that too much cutting causes a heavy strain on the bullocks. If available a lorry can be used to pull the scraper. This is much quicker, but it is more expensive than bullocks.

54. The cost of maintenance of earth roads by a combination of the above methods should not exceed Rs. 100 per mile per annum.

Extract from Engineer in Chief's Technical Paper No. 10: "Road Construction and Maintenance in India".

GRAVEL ROADS.

Gravel is made up of small round particles of stone which occur in nature and are sufficiently large to be retained on a ¼" screen. When a soil contains as much as 40 per cent. to 50 per cent. of gravel and sufficient clay or other cementing material to bond the particles together it proves a satisfactory material for the construction of roads, because it is drained easily and is very stable when compacted.

Ordinarily the selection of gravel for use in road construction must be confined to local materials which are or can be made suitable for the purpose. Since gravel varies enormously in quality it is essential that the Engineer should have some knowledge of the physical characteristics of the various materials and their suitability or otherwise for road construction.

The three chief characteristics which affect the quality of gravel for road work are:—

(1) *The size and shape of the pebbles.*

(2) The hardness of the pebbles.

(3) The proportion and nature of the fines, which act as a binder.

It may appear strange but it is a fact that round material will bind just as well as any other form, and is much easier maintained with a smooth riding surface. Irregular shaped material may bind better to form a crust, but it is not as suitable as the round material for the surface coat. Further, there is less wear in the round stone than there would be with irregular stone, since traffic cannot injure it by knocking off the corners or by reducing its size by abrasion and impact.

For gravel to make a satisfactory surface the stone particles must be graded in size so that the amount of binder required is reduced to a minimum, since it is the stone and not the binder that takes the traffic. Most gravel deposits as they occur in nature satisfy this requirement in so far as the grading of the pebbles is concerned, but they nearly always contain pebbles of a size larger than it is desirable to incorporate in a road surface. For a good surface the maximum size should not exceed 1½ inches in diameter. The qualities which determine the durability of pebbles when used in a road surface are hardness, toughness and resistance to wear. Fortunately most nullah bed bajri contains a large percentage of limestone, which is excellent for road work. Quartz is harder than limestone and gives a good finished surface as it is round and easily worked. Sandstone is softer but works into a good surface as it has good binding qualities. Shaley gravel is usually poor, as it decomposes rapidly into dust under traffic. Normally, in order to determine the best material the Engineer should reconnoitre the sources of supply in proximity to the alignment of the road. It is sufficient to test the hardness of the gravel by breaking the various kinds with a hand hammer.

No matter how durable the pebbles contained in gravel may be, they cannot be used successfully in a road surface unless they can be well bonded together to produce a combined resistance to traffic.

Everyone knows the gravel road that has about 3 inches of loose gravel on top of it, and which is extremely dangerous for motor vehicles. The reason why such surfaces are bad is that there is no binder whatever in

the material. Clay is the usual binder available. The suitability of any particular clay for use as a binder depends upon the same properties as its suitability for use in earth roads, that is, a good non-slaking variety of clay is the best. The clay must be mixed in the proper proportion with sand. The sand content should be at least twice as great as the clay content and the sand and clay, when thoroughly mixed should be sufficient to fill the voids in the gravel.

The grading of the gravel should receive close attention from the very beginning. If the Engineer carries with him a number of small sieves for samples he will be able to analyse in the field any gravel met with and will be able to decide there and then whether it is suitable.

The gravel should be fresh and clean, and be roughly to the following grading, but a good deal of latitude is allowable in the grading.—

1″ to ¾″	15 per cent.
¾″ to ¼″	75 „
Fines below ¼″	10 „

In order to obtain this grading it would be necessary to screen the gravel three times. For rapid work this is not practical. Fortunately most natural nullah bajri is sufficiently well graded in the above proportions for all practical purposes. It is however, always necessary to screen once to remove the large stones over 1″. An expanded metal screen is the most suitable and practical way of doing this. The measurements of the mesh should be 1½″ by ¾″.

One screening must always be done. If the large stones are not removed they remain on the road. They cannot be dealt with by the Auto-Patrol and they are a great nuisance to traffic. They have then to be removed by hand which is very expensive in labour, or else they remain a hindrance to traffic.

When the gravel has been screened once to eliminate the large stones it will readily be seen whether any further screening is necessary. If the sample contains a large proportion of fines it may be necessary to use a ¼″ screen to remove them.

If the subgrade is of clay the above grading is the best, but if the subgrade is sand or silt and if good non-slaking clay is not available, larger stones, even upto 3″ in diameter may be used, as noted on page 88.

Clay Subgrade.—The method of treatment for a clay subgrade is simple.

If we examine an earth road during a dry spell after rain we will find that, as the surface dries out, a crust of hard earth 1½ to 2 inches thick is formed. Below this crust the soil is considerably softer, and contains a greater percentage of moisture. As drying takes place, the effect of traffic is to reduce the crust to powder and then to wear away the softer material beneath. That is to say, the action of the dry weather reduces the moisture content, and then the abrasive action of the traffic removes the crust. Whatever treatment is afforded, therefore, must prevent the drying out of the moisture sufficiently long until a further supply is forthcoming and thus increase the wearing time of the crust to a reasonable limit. In order to prevent this evaporation it is essential to cover the surface of the road.

A comparatively thin layer of gravel on an earth surface very quickly compacts with the earth forming a thin coat which has the property of reducing evaporation and providing a wearing surface for traffic.

The ideal type of gravel surface is one in which the lower portion of the gravel combines with the earth to form a crust, on top of which lies a thin layer of material which can be moved backwards and forwards to fill any depressions that may form. This upper surface will be loose, and it is clear that its maximum size should be comparatively small.

This latter point is of vital importance. The greatest faults of so called shingle roads are that the loose covering is too thick and that the size of the material composing it is too large. In the first case the road will be heavy for traffic, and dangerous owing to skidding on the curves. In the second case it will be rough and the large stones will damage the under-parts of the vehicles. Both these faults are avoided by having the loose layer only half an inch thick and composed chiefly of sharp sand.

For first coat work a depth of gravel of 1½ to 2 inches should be provided. Collection should be ordered for 2 inches. The width for the coat should be 20 feet for 2-way traffic and the full width of the road for any less width of road. The gravel must not be stacked on the road where it will obstruct traffic. The Auto-Patrol will spread the gravel, if it can reach the stacks. The gravel should not be stacked in small wide stacks. These are easier to measure, but they invariably occupy much space and obstruct traffic. Where the road is wide enough the stacks should be at the extreme edge of the road. They should be narrow and high, and also continuous along the length of the road. If the road is not wide enough the stacks must be collected originally off the road and subsequently either spread by hand, or else moved on to the road when the Auto-Patrol is ready to work them.

The subgrade having been brought to its correct shape and consolidated, then and not till then should the gravel be spread.

Before laying the gravel the subgrade should be well watered with water lorries. The watering is of great value subsequently since it provides moisture which is retained when the gravel surface is put down. It also assists in consolidating the lower layer of the gravel.

The spreading may be done by hand or by the Auto-Patrol. It is better to use the latter if it is available. The first coat should be laid 1½ inches deep on a normal clay subgrade. Any large stones that get on to the road when spreading the gravel, or that are torn up from the subgrade by the Auto-Patrol should be removed by hand

The Auto-Patrol should always have a small gang working behind it removing these stones.

If the spreading is done by hand it will not be even. It can be made even very quickly and easily by the Auto-Patrol.

It is quite incorrect to spread earth over this layer of gravel. Traffic itself will very quickly force the lower stones into the clay, whilst the upper portion is retained loose.

Maintenance of clay subgrades.—From time to time it will be necessary to dress up the gravel as the tendency of motor drivers is to take their vehicles straight down the centre of the road, thus forming two ruts and throwing up a little of the material at each side whilst that under the wheels is forced downwards. To drag the material back again is all that is required. This can be done by the Auto-Patrol, or by broom drags.

After a little rain and when the road has been opened to traffic for a short time the crust will soon form. For almost all roads carrying light traffic this single coat is adequate for the first year or two. A road planer run over it once a month will keep it true to shape. If the material is round, the wear will be negligible.

Where the traffic is very heavy, as during operations, it is likely that the crust will be broken through in one or two places, forming very large pot holes. These must be filled in with gravel without delay and before they have time to spread. If 2″ of gravel has been ordered and only about $1\frac{1}{2}$″ spread there will be a surplus of gravel on the side of the road for patching. It is very important to keep this patching material renewed.

The first coat of gravel salvages the road. Subsequent coats improve it. A good gravel road should always have the loose layer of fine material on top which can be worked backwards and forwards with the Auto-Patrol or broom drags to fill up uneven places.

When deluged by rain the water can run away readily to the sides and if the shape is properly maintained by the machines no thin spots or holes will be allowed to form. This loose surface layer should ordinarily be about half an inch thick. For good maintenance this half-inch layer must be retained.

As subsequent coats increase the thickness it will not be long before a full depth of about 5 to 6 inches is reached. Nothing is gained by increasing the thickness beyond 6 inches. Should the road become uneven at this stage the surface should be loosened to a depth of $1\frac{1}{2}$ to 2 inches and the material planed backwards and forwards.

If there is very heavy traffic such as occurs during operations and practically while the road is under construction patrolling by the Auto-Patrol should be continuous. This is very important, and will make a great difference to the road. The Auto-Patrol will keep the surface even and will prevent pot holes from forming. For this work the multiple blade attachment adjusted to a depth of one inch should be used. The Auto-Patrol will do 12 miles of road a day, once over in each direction.

If water lorries are available it is advantageous to water the road in dry weather, as this not only keeps down dust, but also renews and keeps the moisture in the road.

Maintenance by the Auto-Patrol can be greatly assisted by using a drag broom and drag scrapers towed behind lorries. The drag broom is a locally made article and is excellent for keeping a smooth surface on a gravel road. A drawing of the drag scraper is shown at figure 6 of Paper No. 4.

Gravel and shale subgrades.—For gravel and shale subgrades the treatment is exactly the same as for an earth subgrade, except that normally one thin coat ($1\frac{1}{2}$″) of gravel will be quite sufficient to make a very good road. With these subgrades particular attention must be paid to providing good drainage in the first instance.

Catch water drains are extremely valuable for these subgrades, which occur usually in hilly country. If water is allowed to flow from the hill side on to the road the coating of gravel will be washed away and will have to be renewed.

Sand and Silt subgrades.—The method of treatment of sand and silt subgrades is different from that recommended for an earth or gravel subgrade.

When placed on sand or silt, gravel tends to go downwards and in very dry weather which extends for a lengthy period it may get lost altogether. As a gravel road should have a loose surface, a coating of gravel over the sand at first presents a good surface. The difficulty arises in keeping it there. It can be retained by a layer of clay between the sand and gravel, if available. When good non-slaking clay is not to be had close at hand a large coarse gravel will serve excellently. It has the advantage also of being hard and not as easily destroyed as clay.

This coarse material graded between 1½ and 3 inches should be laid on to a minimum depth of 3 inches. This layer will gradually mix up with the sand and furnish a hard base over which the smaller gravel can be laid in the usual way, later on. The larger stones below will hold the moisture for a considerable time thus preventing the fine sand from working up. Subsequent coats of gravel will increase the crust and gradually build up a good road.

A sandy and silty road must be treated according to its nature and according to the analysis made of the soil. It is usually better to put on a double coating of gravel as described above than to use clay, especially if gravel is more easily obtained than good non-slaking clay. Clay cuts up under traffic in wet weather whilst stone does not.

The presence of this additional quantity of stone will cause the moisture to be retained and will delay evaporation. Sand does not become objectionable in a road until it becomes dry and powdery. The double thickness of gravel prevents powdering. If clay is used it must be remembered that it will pulverise in dry weather if applied above the sand in too thin a coating. The thickness of the clay should not be less than 3 inches for 1½ inches coating of gravel. The greater the thickness of clay applied the nearer it approaches an ordinary clay road. The total quantity of clay and gravel depends entirely on the nature of the sandy surface being covered.

With intensive traffic the first or first two layers of gravel may disappear altogether. Anything up to 1′ 6″ thickness of gravel may have to be provided if the soil contains 70 per cent. of silt.

Maintenance of silty subgrades.—In dealing with a very silty subgrade it is of even greater importance to patch quickly than it is in the case of the good clay subgrade.

Also, watering becomes of very great value, and the arrangements for bringing water quickly on to the road must be complete.

As soon as one coat of bajri has been spread on roads of the description orders should at once be given to collect another coat. There should always be one coat of bajri in reserve alongside the road.

The tendency of gravel roads to develop a wavy or corrugated surface is particularly noticeable in the case of sandy and silty subgrades. If the corrugations are not too deep and especially if the work is done while the road surface is moist, the tops of the corrugations can be cut off by the use of either a grader or the Auto-Patrol. The material thus removed is spread uniformly over the surface and compacted by traffic. It should be continually worked back and forth and kept in a smooth condition while it is thus being compacted. A small amount of moisture in the road surface adds materially in its cementing or bonding together. Too little or too much moisture will prevent the proper bonding.

If the roadway has been allowed to become deeply rutted or very wavy under the action of traffic, the surface may have to be scarified and bladed into proper shape. This scarifying should be done to a depth equal to at least the depth of the corrugations. The scarifier attachment for the Auto-Patrol is an excellent tool for this work. It should be borne in mind, that large rocks in the road bed interfere with this method of reshaping and they should be removed from the surface before starting the work.

Lieutenant-Colonel A. V. T. Wakely (the Author): Mr. Chairman and gentlemen. The only additional remark that I would like to make is to stress the importance and value of the *Auto-Patrol* that we saw in Peshawar It is a maintenance machine, and we find it extremely valuable for the maintenance of earth roads. The one you actually saw in Peshawar did not have the ordinary blade fixed on, but it had the multiple blades. The ordinary blade is used for the first two or three rounds and the multiple blades are for smoothing. The *Auto-Patrol* is a very rapid working machine for the maintenance of earth roads, and we have actually done up to five miles per day of finished road with it. (Applause).

Chairman: I will now call upon Mr. Breadon to introduce his paper and to make any additional remarks he wishes to make. After that, we will consider both papers together, as I think they relate largely to the same subject.

The following paper was then submitted for discussion:

PAPER No. 3.

EARTH ROAD CONSTRUCTION AND MAINTENANCE BY MACHINERY.

By G. W. O Breadon, District Engineer, Gurdaspur. Punjab.

These notes relate exclusively to *EARTH ROADS*, which, all Engineers will agree, must form the backbone of Communications in India, even if, when the financial position improves. India embarks on a programme for extending her hard road system.

2. *Earth roads*, under all conditions. will. for all time, remain the *peoples' roads, i.e.*, the District Boards' Roads. It follows that any improvement in methods of construction and maintenance are of vital importance to District Boards and also to the whole Province.

3. My experience is that *a good earth road can be maintained in satisfactory* condition for easy travelling for the greater part of the year and in a fairly passable state during the rains also. Tractors and the graders have been tried out in the Gurdaspur and several other districts in the Punjab. In the Gurdaspur district these mechanical appliances have done comparatively good work and have done it fairly cheaply, but from my experience, as a highway Engineer, I was not satisfied with the plant employed, its output and the cost of operation. This was not because the tools are unserviceable, but because the outfit is incomplete. District Boards are ill-advised to invest in complete plant which could not, therefore, yield the best results.

4. For road construction and maintenance an outfit should consist of :—

Two graders fitted with scarifiers and back slopers.

Two tractors for graders.

One road planer, or smoothing drag, or so called " Maintainer ".

One tractor for road planer.

One triple set of road rollers (6 tons).

One tractor for rollers.

One motor lorry for transport.

Four tents for operators and coolies.

5. The outfit described above is not too costly for most District Boards to invest in. I have not yet obtained such a complete outfit, but the Gurdaspur District Board has provided two tractors, two graders, one maintainer, one set of triple road rollers, two bullock carts and four tents for staff, and I feel sanguine that two more tractors will be provided next year. With the plant now in use I am able to grade from 4 to 4½ miles of road per day, but with a complete outfit there is no reason why 10 miles of road should not be completed in one day. The plan attached shows the sequence of operations in which a complete outfit should proceed along the road.

6. The advantages that this system offers are threefold.

Firstly.—About 10 miles of maintenance work, including drain-excavation, surface-cutting, surface-forming and consolidation, can be executed in a working day of eight hours; that is 60 miles of road can be improved weekly, without the operators being inconvenienced, as a lorry enables them to change camp daily. In this manner all roads in this district can be graded at least three times a year without disturbance to traffic.

Secondly.—It is the most economical method of road maintenance and road construction. The cost of improvement by manual labour is about Rs. 1,500 a mile and subsequent maintenance varies between Rs. 200 and Rs. 350 a mile, whereas a mechanical outfit, including all working charges and depreciation, can do the work more quickly, more efficiently and far more economically. Improvement costs approximately Rs. 60 per mile and maintenance from Rs. 20 to Rs. 40 per mile, according to the nature of work and season in which it is executed.

Thirdly.—There is efficiency with no disturbance to traffic. The whole outfit operates simultaneously; a grader works on each side of the road cutting a side drain, sloping the edge of the road and conveying the loose earth on to the road; the planer or drag following spreads the earth evenly over a width of 9 ft. along the road surface and at the same time cuts down and smooths over all irregularities in the road; while the rollers in their turn consolidate the earth leaving behind them a finished road ready for immediate use. Nothing more desirable could be wanted for we have in this outfit *SPEED, EFFICIENCY, FREEDOM FROM CLOSURES AND ECONOMY.*

7. During the year 1931-32 about 200 miles of earth-roads in the Gurdaspur District were maintained—a tractor and grader alone being employed. The work was good and the condition of roads was materially improved at an average cost of Rs. 52 per mile for the first grading, against an estimated cost of Rs. 100 per mile for 2 gradings each year; but the great drawback throughout was the looseness of the road surface, which is, as can be readily realised, a great hinderance to all forms of wheel traffic. A loose surface, too, is quickly rutted by bullock carts and lorries, which calls for a second light dressing-cut within a very short time of the first operation. In my opinion the grader, without the planer and rollers, can not, in producing a cheap and serviceable earth road, compare with a complete outfit.

8. Referring to the attached plan, I desire to point out, that when the existing side drains of a pre-graded road are in a fairly serviceable condition it is not necessary for more than one grader cut to be made on each side of the road, in order to provide sufficient earth for the making up of the road surface. The width of the road is determined by the spread of the blades of the maintainer, which in the case of MacCormic Deering No. 61 planer, is 9 feet. The mounds of earth left by the grader should, therefore, not exceed 8 feet from outside to outside. When spread over the surface of the road by the long moveable blade behind, the width is increased to about 10 feet which is easily covered by the rollers. Should a larger quantity of earth be required for the roadway, and it be also desirable to widen and deepen the side drains, the graders will have to make two cuts on each side of the road, the first cuts being 18 feet apart and done independently of the maintainer and rollers.

These will not come into operation until the graders are making their second cut, which will be in parallel lines 14 feet apart.

NOTE.—It is very important, not only for the sake of appearance, that the first cut made by the grader should be straight, as all succeeding cuts are governed by the first, and any irregularity which appears in the first cut is likely to persist in the finished ditch. It is even more important when a maintainer is in use that the guide lines for the grader should be accurately laid out and be parallel.

9. *Punjab*.—Roads in the Punjab are divided into four classes:—(1) Arterial, (2) Class 2 or main roads, (3) Class 3 or entirely District Board roads, (4) village roads. Under the Head Arterial Roads there are 4,720 miles of which 2,150 are metalled and 2,570 are unmetalled. Arterial Roads are maintained exclusively by the Public Works Department from Provincial funds. The total mileage of Class 2 or Main Roads is 8,160, of which 1,150 are metalled and 7,110 unmetalled. The total mileage of Class 3 roads is believed to be 11,000, of which 150 are metalled. There are about 40,000 miles of village roads in the Punjab, but actually they do not deserve the name of road.

10. From the above it will be seen that Punjab highway system includes about 20,500 miles of earth roads and 3,600 miles of metalled roads and were the Province to embark on a programme of metalling the whole system it would take about 100 years to complete at the colossal cost of Rs. 41,00,00,000 which represents the initial cost of construction only. It is obvious, therefore, that this Province will have to depend mainly on earth roads and, in order to improve and maintain such roads, it will have to resort more extensively to the use of machinery.

11. In order to open up the country rapidly and economically, I would urge upon Government the proposal of combining its Railway, Roads and Rural uplift policies, whereby a larger number of feeder earth roads and even village roads can be improved for motor traffic and some restrictions placed upon the transport of goods and passengers by motor vehicles along arterial roads running within a distance of 10 miles on either side of Railways. If this could be done motor lorries would find their way into the remotest of villages, from which passengers and goods will be conveyed to Railway stations. The revenue of the Railways will thus be increased, while the owners of lorries will have no occasion to complain of loss of business. Incidentally with the improvement and the extension of the earth road system Government, as well as District Boards, should be able very materially to reduce the cost of education, which is at the present, a drain on the resources of District Boards.

12. *Soils*.—Speaking generally from a constructional point of view, there is hardly a soil which is wholly unsuitable for an earth road. It is, however, admitted that some soils are bad, but it is not difficult, nor is it costly to improve the surface so as to make the road serviceable for motor vehicle and bullock carts.

(1) A clay-loam (containing about 60 to 70% of clay) makes a road which will stand up to heavy traffic.

(2) A light loamy soil (containing over 40% of sand) is not to be despised, provided that it is graded and rolled when there is some moisture in the soil. This road will easily carry moderately heavy traffic, but should it break up

under heavy loads, a 3 inches to 6 inches layer of clay spread over the surface at the time that the 2nd grading is being done will, when rolled, remove all difficulties.

(3) Soils impregnated with certain salts are about the best for earth roads, but

(4) Where salts are in excess, they can be remedied by either clay covering the surface or by spraying with the crudest of earth oil.

13. From actual experience in this District I have found that the worst sections of roads in weak soils can be improved and brought up to a high standard by clay-covering at an average cost of Rs. 500 per mile.

14. *Selection of Plant.*—The experimental stage has passed and we are now definitely able to state what makes of tractors, graders, maintainers and rollers are best adopted for the mechanical construction and maintenance of earth roads.

(a) As regards tractors, I prefer those manufactured by MacCormic Deering. For light draught work the 15/30 H. P.—is generally suitable and for heavier work the 22/36 H. P. wheel tractor will be found very suitable. The T 20 Trac-Tractor is also a very good machine, but it has one weakness in its track rollers, which the manufacturers have been advised to remove. The Caterpillar tractors have also given very satisfactory service on the North-West Frontier; while in Kenya the Director of Public Works has found the HOLT No. 30 Caterpillar, the Sawyer Massey No. 80 grader with scraper and back sloper and Ransomes Duplex Water Ballast Roller to be the most suitable for his work. As a matter of fact that tractor is best the gears of which are suitable for earth road work. Most British machines are unfortunately unsatisfactory for this reason.

(b) *Graders.*—The Graders which I have used are the Adams leaning wheel No. 7 and the Stockland grader and have found both equally serviceable.

(c) *Maintainer.*—My experience in regard to maintainers is limited to Adams No. 61.

(d) *Rollers.*—Our set of triple rollers was manufactured by a Bombay firm, but unfortunately the frame is weak.

SCHEDULE OF CONSUMPTION OF FUEL-OIL, ETC., BY GRADING OUTFIT AND COST OF GRADING PER MILE TRAVELLED.

15. For the purpose of checking the cost of grading I give below the average consumption of oil, lubricating oil, etc., also cost of labour and depreciation on an outfit consisting of one T. 20 Trac-Tractor and one Adams leaning wheel grader :—

(1) Kerosene oil=0·93 gallons per mile travelled.

(2) Lubricating oil=0·08 gallons per mile travelled

(3) Petrol=0·02 per mile travelled.

(4) Grease=0·02 lbs. per mile travelled.

(5) Thick lubricating oil=0·07 gallons per mile travelled.

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(6) Miscellaneous (Lime soap, cotton waste, etc.) =0-4-3 per mile travelled.

(7) Establishment=1-1-8 per mile travelled.

(8) Depreciation=1-6-8 per mile travelled.

NOTE.—The cost (not including repairs and depreciation) should ordinarily not exceed Rs. 2-8-0 per mile travelled. The total cost including repairs and depreciation for the year 1933-34 worked out to Rs. 4-0-9 per mile travelled.

16. During five months of the current year the cost of working an outfit consisting of a T 20 Trac Tractor, a 22-36 MacCormic Deering wheel tractor, an Adams leaning wheel grader, a Stock Land grader, a 61 maintainer and a set of triple rollers (6 tons) is as under :—

Kerosene oil=$2\frac{1}{8}$ gallons per mile travelled.

Petrol=1 gallon per 50 miles travelled.

Mobile Oil=1 gallon per 12 miles travelled.

Gear Oil=1 gallon per 35 miles travelled.

Grease=1 lb. per 16 miles travelled.

Miscellaneous (cotton waste, cleaning cloth, soap, etc.)=3 pies per mile travelled.

Establishment Re. 0-13-6 per mile travelled.

Depreciation Rs. 3 per mile travelled.

Lime for marking road 1 maund per mile travelled.

NOTE.—The estimated cost including all charges is Rs. 8 per mile travelled.

17. *Establishment.*—Establishment employed on working the above machines consists of :—

	Rs. p. m.
1 Tractor Driver-mechanic	70
1 Tractor driver	42
2 Grader operators at Rs. 40 each	80
1 Jemadar	20
8 Khalasis at Rs. 15 each	120
2 Cartmen at Rs. 40 each	80
Total ..	412

I would, however, like to have a mechanical overseer with road experience to supervise the work paying him Rs. 100 p. m., which would be more than covered by the additional work which could be done if the Tractor-driver were relieved of setting out the work and general supervision.

18. *Maintenance of Machinery.*—It is most important that the District Engineer should engage thoroughly trained and competent men as operator and also exercise frequent supervision in order to see that his men are keeping

all machines clean and faithfully carrying out the instructions of manufacturers in the proper lubrication of all parts.

19. *Spare Parts.*—The District Engineer should arrange to keep in stock a suitable number of cutting blades and such other parts of machinery as require frequent replacement. He should also obtain an undertaking from the agents, through whom machines have been purchased, that they themselves will maintain a well-stocked spare parts department in India, preferably in the Province where the machines are operating.

20. *Manual Labour.*—Despite the fact that a grader can conveniently raise a road to a height of 2 ft., provided that sufficient land is available on both sides of the road-way, from which spoil can be cut and conveyed to the bank, we cannot entirely dispense with cooly labour in the construction, improvement and maintenance of earth roads. Manual labour is necessary for (*a*) repairing bridges and culverts and in keeping their approaches in order; (*b*) closing breaches in roads and in raising such portions of the road where machines cannot operate; (*c*) clay covering sandy stretches; (*d*) grubbing out stumps and roots of trees; removing jungle and large rocks; (*e*) cutting outlets from drains; and (*f*) keeping road crossings in proper order.

21. *Limitation of size of Motor vehicle.*—If the proposal that I have made above to improve earth roads and even village roads be carried into effect it will be advisable in the interest of the roads not to allow very heavy vehicles to ply for hire. It is a mistake to suppose that India, with its millions of small land owners, will ever lend itself to the employment of large trailers drawn by diesel oil engines or multi-wheeled trucks in any case their introduction should not be encouraged, but every assistance should be given to small lorry owners.

22. *Conclusion.*—It is most important, where mechanical tools are used in the development and maintenance of roads, that the machinery so employed should be kept in constant commission. Breakdowns cannot be altogether avoided, but they can be considerably reduced, if a trustworthy superintendent is in charge of the plant and if the District Engineer exercises reasonable supervision. No restriction should be placed upon the Engineer in the immediate replacement of worn-out parts and in the execution of essential repairs. Unfortunately some rules framed at a time when the use of mechanical tools was not contemplated, appear to be excessively restrictive in this respect.

DISCUSSION ON PAPERS Nos. 4 AND 3.

Chairman: In the first place, I should like to thank the writers of the two papers for their extremely interesting, able and well written papers. Personally, I have no experience of roads of this kind, and I have read both these papers with much interest. I can hardly believe that the authors attained the results they claim to have attained and I only hope that what they tell us is true. (Laughter). There is one point that struck me particularly—one on which both lay emphasis,—and that is, they say that the whole success or failure of the system depends entirely on good organization. Yet it is suggested that supervision of a less high order is necessary than is the case when constructing roads of a more permanent nature. I can hardly think that this is the case. It seems to me that if this expensive machinery is to be kept in full commission and made the utmost use of, one would want a staff with great initiative and foresight. In fact, you want men of a better quality than are required for the maintenance and construction of metalled roads. I hope that in replying the writers will refer to this point more fully, because, it is a criticism that I have heard made by other people as well. There is one other point I would like to mention and it is this. As far as I can see, the whole of the work is done by departmental labour, and it is not possible therefore for the engineer to pass any of his responsibility on to the contractor, as we can do in regard to our road work. Here, if things go wrong, to a certain extent we can hold the contractor responsible. In the case of these earth roads this does not seem possible.

Mr. D. Macfarlane: Mr. Chairman and gentlemen. Mr. Brebner has just referred to the fact that when graders are employed, a higher class of supervision is required, and I think, there is a lot in what he says. The graders in the Punjab were introduced some time ago, I think very greatly through the energy of Mr. Stubbs, when he was Secretary of our Communications Board. In the Punjab the District Boards are the people who are primarily interested, because they have far more unmetalled roads than other Departments. Mr. Stubbs inaugurated this system of graders and persuaded the District Boards to purchase them. I am sorry to say that in recent years the graders have gone very much into disuse, and Mr. Stubbs has been away from us for the last year, but I can assure him and others that these graders have gone so much out of use that recently the Punjab Communications Board have devised a separate Fund which they set apart from the grant-in-aid which they give to District Boards as subsidy so as to encourage them to bring these graders into use again. One of the excuses that is put forward by the District Board Engineers for their disuse is the difficulty of getting spare parts, but my own experience with regard to any form of mechanical work is that unless it is done on a really big scale, the question of spare parts will arise, and it is really a difficult question. If a District Board has perhaps only one or two graders in use in the whole of the district, and if those get out of action, then it must take a long time to get the spare parts, and the result is, that they revert to the original methods. I think you will find that it is exactly the same thing with any form of mechanism. If you have got a really good and efficient organization and a good workshop the thing is entirely different. Two years ago when we were rebuilding the Kohala Bridge, the whole of the transhipment of steel work, pneumatic rivetting plant, etc., from rail head at Rawalpindi to site—some 65 miles away was done by the I. A. S. C.

who very kindly undertook this work for us and the thing worked marvellously. I remember one day passing a perfectly good four-wheel drive lorry with nothing in it. I asked the driver where he was going, and he replied that he was going to Kohala, because they had had a wire the previous night from there to say that one of their lorries had broken a back axle and he was taking down a new one. Now, if you have a perfect organization like that, all is well, otherwise if anything goes wrong, the lorry or in this case the grader is merely left by the road side and the staff reverts to the ordinary hand labour. (Applause).

Chairman: I suggest, gentlemen, that we should adjourn now and continue this discussion to-morrow morning at 10 o'clock.

The Conference then adjourned till 10 A.M. on Wednesday, the 12th December 1934.

Third day, Wednesday, December 12th, 1934.

The Congress re-assembled at 10 A.M., Mr. B. F. Taylor, (Chief Engineer, Assam) in the Chair.

DISCUSSION OF PAPERS Nos. 3 AND 4—(*contd.*).

Chairman: Gentlemen, yesterday afternoon we left off during the discussion of papers 3 and 4. We will now proceed further to hear anything that anybody else would like to say with regard to those two papers.

Mr. S. G. Stubbs: Mr. Macfarlane mentioned yesterday that perhaps I would be able to say something about road grading in the Punjab. Well, it is about five years since I have had anything to do with it, so my knowledge about details is rather hazy. I think it will meet the case if I read out two paragraphs of a paper* on Earth Roads I wrote nearly five years ago.

"As early as 1921, the Communications Board of the Punjab realized the very great importance of unmetalled roads and had been impressing upon District Boards that earth roads are of definite economic value and can be kept in excellent condition if the soil is suitable and proper attention is devoted to them. With this object in view demonstration earth roads were constructed by manual labour in 20 districts. These roads were already in existence, so the work really consisted of improvement. This consisted of restoring the camber by 6 to 8 inches of earth filling, watering and rolling, repairing existing culverts and providing new ones where necessary. To give the experiment a fair trial, the Communications Board entirely financed the cost of improvement and subsequent cost of maintenance for one year. In all except three cases, all these roads were in excellent condition after a year. Though these results were very satisfactory, this method proved comparatively expensive, improvement costing about Rs. 1,500 a mile and subsequent maintenance costing about Rs. 200 a mile. Therefore activities in this direction were somewhat restricted until the introduction of tractors and graders, when sufficiently successful results had been attained to predict with some measure of certainty that the use of road-grading plant would go a long way towards solving our road problem, and further, owing to the reduction of cost of maintenance we could look forward to seeing progress maintained at a very rapid rate. Within the space of two years, nearly 2,400 miles of earth road will have been improved, and if this progress can be maintained it is not difficult to visualize the extent of the benefits which will accrue within a very short time." Mr. Mitchell saw some of these roads after two years, and I think he can vouch for the benefit derived from the use of these machines.

"Now another important point is about the maintenance of plant. To ensure that plant was properly handled, the supervising and operating staff of District Boards were properly trained before assuming control, and to safeguard District Board's interests the suppliers of new machinery were expected to run the plant for six months with their own staff, the District Boards paying actual running expenses, and if the plant proved satisfactory

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* Paper No. 137 read at the Punjab Engineering Congress.

District Boards were expected to purchase it. From the point of view of the suppliers these conditions appeared somewhat drastic and were by no means popular. But it was felt that unless District Engineers and their staff were properly trained and an adequate supply of spares maintained, the machinery would soon be out of commission. Also during the probationary period of six months the District Engineers and supervising staff were trained to operate the plant with their own hands. A daily log was maintained for each outfit showing fuel consumption, other stores, and amount of work done. This enabled the Engineer Officer on the Communications Board to keep in close touch with the performance of each machine. In addition frequent inspections were made by Assistant Engineers and the Mechanical officers of the Communications Board, as well as by the Engineers and mechanicians of the suppliers. By these means those in local control were kept up to the mark and serious breakdowns were reduced to a minimum." The Assistant Engineers were specially trained for the job. I deputed three of them to spend a week in the workshops of one of the suppliers to put a tractor together with their own hands, and they were also trained to operate these machines with their own hands. So they knew something about their job, and that is how we kept these machines going. I understand that since that control was removed, things have died a natural death.

Diwan Bahadur N. N. Ayyangar: Mr. Chairman and Gentlemen, we ought to be very grateful to the authors of the papers for introducing this important subject. We have already got the main communications developed in India, and the next great move required is the development of rural roads. The number of miles required for this purpose may be roughly calculated I think at not less than three million miles. You will see therefore that it is a colossal work which cannot be undertaken except with the aid of modern road-making machinery. The difficulty which arises in connection with this road-making machinery lies in the organization, as pointed out by various speakers previously. Village roads are in the charge of local bodies or village organizations like Panchayets, Unions, etc. So these people are not in a position to employ an establishment competent to deal with mechanical appliances. At the same time there are firms in the important cities who deal in this machinery but who are not in close touch with these various local bodies in rural areas, and so difficulties arise at both ends through this non-contact. As a result we have instances of failure as described by Mr. Macfarlane. I do not think that the use of these machines could have been made in more favourable circumstances than those described by Mr. Stubbs, yet even there they have not been successful. I think one remedy would be this. We have got these firms in the Presidency Towns and we have got a large number of graduates trained in mechanical and electrical and civil engineering in our own Colleges who have got no jobs and no capital. So what I would suggest is that the firms dealing in this machinery should encourage these people and help them to form private companies on business lines and give them machinery, the cost of which might be recovered in small instalments on the hire purchase system. If this is done I think we will create a new agency for furthering the use of these machines, whose living will depend upon maintaining these machines in efficient condition. There are thousands of miles of village roads to be made and maintained and such intermediate agencies would be beneficial to suppliers and rural bodies alike. I therefore suggest this may be considered by the firms and various bodies concerned.

The next point on which I wish to speak is as to the composition of the material for making these earth roads. In this connection a number of points have been referred to in this paper. I agree with most of them, but disagree with a few. I entirely agree with what Colonel Wakely says at the end of para. 7 of his papers that "in any road scheme it is a question of rendering the greatest service to the greatest number of people at the least cost, and it is suggested that it is more important for the good of the country generally to develop these subsidiary feeder roads in a proper manner than to spend large sums on ambitious and luxurious main road schemes". Then in para. 10 Colonel Wakely says, "On a wide road, traffic distributes itself and uses the whole width and the evil of tracking is largely eliminated." I doubt that very much, because, whatever the width of the road, there is a tendency for bullock carts or motor-vehicles to follow just the centre of the road. In Southern India you always find miles and miles of wheel tracking formed on macadam roads, and I do not think it differs much in Northern India.

Then in para. 23 he says, "For instance, a road soil that is 95 per cent. *sand will not cohere, and a clay that does not possess the property of* cohesion is useless as a road material and will do nothing but make dust". Well, I do agree with that, but I do not think that a material which does not possess cohesive properties can be called clay at all. It must come under sand. Then in para. 26 the best proportions are said to be, sand 70 to 85 per cent; silt 10 to 20 per cent; clay 5 to 10 per cent. There are various kinds of soil, and of which there are two extremes. One is the typical black cotton soil of the Bombay Presidency, Madras and Central India. This becomes very slushy in the rains but remains very firm in the dry season. At the other extreme you have the extremely sandy soil of the Indo-Gangetic plain and Sind and the deltaic areas of the Madras Presidency and parts of Northern Gujerat. This remains hard when wet in the rainy season but in the dry season it powders because it has a very small clay content. Therefore the problem is to get an intermediate composition of the correct consistency. What is that proportion? I have seen certain places in Mysore and examined the soils and gravels which make very good roads, and in those cases the proportion is one-third clay and two-thirds sand or pebble or shingle material. If these two are mixed in that proportion I think it makes the all-weather road required for our purpose, that is, a good cheap earth road. The problem really is to get that proportion in every place because it varies from place to place. Now in the same para. Colonel Wakely says, "It will usually be sufficient to consider silt and clay together without separating them." I do not agree with that at all, because silt does not bind, and if there is an excess of silt you will either have a quagmire or a mass of dust. In order to get the correct proportion which is, roughly, two of sand and one of clay, I employ a certain method which I will now describe to you. To ascertain the sand and silt content of any sample of soil roughly, put, say 10 cigarette tinfuls into a bucket of water and after stirring it thoroughly with the water, pour off the muddy liquid. After three or four such washings what is left will be the sand and silt content of the soil. Now measure the residue with the same tin. Suppose it measures 6 tins; the percentage of gravel is 60 per cent. Now I use the formula: $100-1{\cdot}5G$, for getting the percentage of gravel or sand to be added to get the correct proportion (G, is the percentage of gritty material in the soil). In the above case the quantity of gritty material to be added is therefore $100-1{\cdot}5G=100-1{\cdot}5\times60=10$ per cent.

Where the clay content of the soil is less than 33⅓ per cent, and clay has to be added to get the correct mixture the same formula would be used but expressed as 1·5G—100 for convenience.

Then in para. 27, in connection with reconditioning an old road and as to the depth of treatment to be given, it is said "Normally 8 inches should be aimed at." I think that is very sound depth to have.

Mr. J. M. Fetters: I shall say a few words relating to the maintenance of roads in India. The earth roads of India will be largely built by district and local boards who on account of their limited resources can neither afford to purchase big plant nor to pay the high cost of supervising. I think the question was raised yesterday that it was rather difficult to use tractors and graders without highly trained personnel. In a big country like India, district and local boards are widely separated from each other and the solution of this question is not for the district and local boards to hire the highly trained personnel, maintained by the manufacturers and dealers, who will be able to undertake the mechanical repairs and do the supervising; but this function ought to be performed by the agents. If we leave this to the district and local boards and the small owner who can own probably only one or two machines, then they cannot afford to spend the money to maintain them. This work could be easily done by the dealers and agents maintaining a highly trained engineering staff. We are all of us trying to train our people. They must be trained on the actual machines. That is going to take some time. I think practically every dealer and manufacturer is maintaining adequate stocks in India and also engaging highly trained staff of engineers who will be available for hire. A word about the selection of plant. It cannot be said that a grading plant consists of a particular number of machines. Actually, each road problem has got to be tackled on its own merits. Every problem should be studied carefully before the plant is purchased. A plant which might work satisfactorily in the Punjab might be a failure in Mysore and *vice versa*. Each particular installation should be examined carefully by a person who has knowledge of grading, stabilisation and so on before the plant is purchased. Many of our failures in India are due to the fact that graders and tractors have been looked upon as the be all and end all of earth roads. It is a question of the training of the personnel and the selection of plant and the use of that plant after it is purchased, which makes earth road building successful. There are other machines besides tractors and graders, for the making of earth roads. We have scrapers, plainers, patrols, maintenance machines of various descriptions and machines of varying size to suit each particular requirement and the thing that I want to say and which is extremely important is 'Be careful about the selection of plant'.

Mr. D. Daniel: We are greatly indebted to Lt.-Col. Wakely and Mr. Breadon for their very useful and practical papers on the subject of earth roads. We have a few grader outfits in the Madras Presidency. The cost of making one mile worked out from Rs. 200 to Rs. 320 and the subsequent maintenance Rs. 50. This was more or less the same as the cost with manual labour. On good soils the outturn may be a little more. Lieutenant-Colonel Wakely has estimated the efficiency ratio for grader work to be 1·56 to twice that by manual labour. Mr. Breadon in para. 6 of his paper has stated that the cost of making an earth road can be reduced from Rs. 1,500 to Rs. 60. Probably no allowance for depreciation or interest is made. In any case I should think this great disparity requires some more investigation. As regards soils, Mr. Breadon says there

is hardly a soil which is wholly unsuitable for an earth road. We have in the Madras Presidency problem of black cotton soil in some districts. I believe similar is the case in some other provinces also. It is very difficult to make an earth road in such soil, which is peculiar silty clay. When wet it becomes waxy and rolls up on the wheels and no vehicular or even animal traffic is possible in wet weather. No amount of sanding can improve it as the soil never mixes up with the sand even for years. I have brought samples of soils here and if Mr. Breadon cares to examine them, he might see and explain how best to improve them. We generally improve such soil by gravelling it, which to some extent waterproofs it. Such a road is found to be better than a mere mud road in a locality which has a rainfall of 50 or 60 inches as compared with only 15 or 20 in the Punjab.

Looking at the diagram before reading Mr. Breadon's notes, I wonder what is to happen to the daily traffic. The first three units completely obstruct the traffic. The last one with the 3 rollers completes the blockade. Even if the first three units can be made to work far apart, the last one has necessarily to occupy the full width. Hence the statement in paragraph 6 that there is efficiency with no disturbance to traffic requires, I think, some more amplification.

In fig (2) of Colonel Wakely's paper, the right method of making an earth road is shown with an embankment of 3 feet or 4 feet in order to avoid saturation. With due deference to Colonel Wakely, for whom I have come to have a personal regard after this recent tour, I should like to state that our experience in the Madras Presidency is somewhat different. We have nearly 50 to 60 inches of rainfall on one coast and about 100 to 150 on the other. We have therefore endless troubles on many roads with high embankments. The edges get eroded whenever it rains and sometimes to a dangerous extent. The first one or two coats of metalling sink, unless soling is laid, which is costly. Roads made on low embankments, or level with the ground, having two good side drains and cross drains at intervals are found to work more satisfactorily than roads on high embankments. The roads are raised only at places where water is expected to collect. In this way I have reduced the cost of formation in one district from Rs. 1,700 per mile to Rs. 450 a mile. I find also such roads easier and less costly to maintain in subsequent years. I also find that the Royal Engineers who were responsible for the construction of trunk roads in that presidency have adopted the same principle. Hence I think that in provinces with heavy rainfall the disadvantages of taking roads on high embankments far outweigh any advantages claimed.

As regards the scope for earth road maintenance by modern machinery in the Madras Presidency, I should say it is somewhat limited. In the Punjab, 75 per cent of the roads including many miles of provincial roads are said to be unmetalled. In Madras, it is just the reverse owing to the fairly heavy rainfall and availability of metal in many parts. The earth roads are therefore for the most part minor village roads which are generally narrow and run between wet fields or channels. The few main earth roads in deltaic tracks have large grown up avenue trees very close to the margins precluding the use of graders. There is also a suspicion lurking in the minds of local bodies that the introduction of this machinery for earth roads is likely to create unemployment among the rural population. I thank the authors of the papers once again and particularly Lieutenant-Colonel Wakely for his able and complete treatment of the subject. I also take this opportunity of thanking him for the extremely amiable manner in

which he showed us all the works he had done illustrating everything in a clear manner at a very great sacrifice of time and energy.

Chairman: Unfortunately Colonel Wakely has had to leave and he will not therefore be here to reply in person to the criticisms and suggestions made on his paper. They will however appear in the proceedings. I should like to express my personal thanks and the thanks of the delegates from Assam to Colonel Wakely for his most interesting papers and in particular for the perfectly fascinating tour he gave us in the North-West Frontier Province. (Hear, hear).

Before I ask Mr. Breadon to reply to the discussion on his paper, perhaps you will allow me to say a word or two about the use of road machines in Assam. We in Assam claim to be pioneers in this method of treating *kucha* roads as we call them. We have been doing it for many years and the first road machine which I think ever came to India was purchased by myself. It was a self-propelled contration. The machine was large and powerful and it demonstrated quite definitely and at once that such treatment of earth roads would be practically revolutionary. It also showed straight away that it was totally unsuited to our conditions. Nearly all our roads are on embankments with very narrow crests, interrupted every mile or two by timber or bamboo bridges and over the major rivers by ferries. We must therefore have machines that we can get across those bridges and ferries. We find that the self-propelled vehicle is useless and we have concentrated on tractors. We made very extensive trials with various kinds of tractors. It is obvious of course that it is more economical and handier in the long run to have the whole fleet of one make. We tried Bates, Fordsons, Cletracs and several other makes. We have now got an entire fleet of caterpillar 25 which we have found so far the best suited to our requirements. I regret to say that we have up till now been unable to get a British tractor of the type we want. Between ourselves, I think this is perfectly disgraceful. When I was at home last year, I was asked by a firm in England to see a machine which they were developing for agricultural purposes at home. It seemed admirably suited to our requirements. It was a Diesel engine and of about 50 horse power and was too large and too heavy. We want something about 25 h. p. The attraction of this tractor to me was its type of track which had no track pins and no track-pin bushes, which are the bane of our existence in Assam. The track has hard rubber lock joints and it is claimed that those can be changed in half an hour without removing the track from the machine. I understand that such a track has not yet been properly tried out, but something of that nature is clearly what we are on the look-out for in Assam as this question of track-pin and track-pin bushes is a very acute one. The conditions under which we work in Assam are in no way comparable to what we saw in the Punjab. Our machines have as a rule to work in mud or very damp road soils.

In regard to what we term a road unit, I notice that in Mr. Breadon's diagram at the end of his paper, he has got no less than four tractors in his road unit. If he will allow me to say so this is most extravagant. We have worked with one and make that tractor pull not only a planer, but a roller as well. We find the planer gets you there quicker than the grader, for ordinary petrol or maintenance work. In the wet weather we use drags. With regard to the last machine of his, the roller. In

America, I understand, where they use these road-machines very extensively, they never use rollers. It is no good our scraping up the soil of a road if it is going to have a shower of rain in two or three hours afterwards and become a morass; therefore we have to consolidate the loosened soil at once. Our trouble was to get a roller made in such a way that it would take the camber of the road. Mr. Breadon has produced a triple-roller, it is merely three ordinary ballast rollers mounted in a steel frame and hung in spring axle boxes which permit them to follow the camber and unevennesses of the surface. If it is of any interest to any of the States or Provinces here represented, I will be very glad if they will write to us and we will let them have plans of the arrangements. It is an excellent machine and one of its attractions is that it does not have to be reversed but can be yoked from either end. At a difficult river crossing, the rollers can be taken over individually.

Now with regard to costs, I may say at once that we are very ashamed that we in Assam have not produced a paper. But our conditions are so peculiar to ourselves that we were very diffident about it and doubted if it would have been of much interest to the rest of India; climatic conditions in Assam may be similar to parts of Madras or Eastern Bengal but they are not comparable with those in the Punjab or N.-W. F. Province or this part of the world. But with regard to costs, we have kept very elaborate returns of all the movements of our machines. It is however very difficult to arrive at a figure for the cost maintenance per mile. There are no two miles the same. In many cases our road train has to proceed several miles before it gets to work at all. You may have one mile of road which only needs one trip over it or you may come up against a mile of road which takes a machine a whole day to treat. There is therefore a great difference between the cost of the mile treated and the cost of the mile travelled. We have, however, devised a new return from the 1st of last April in which we hope to produce the cost of a mile treated, and therefore by the end of this year we ought to be in a position to give you quite definite figures as to the cost of a mile treated. I think it was Mr. Brebner, yesterday, who cast doubts on the cost of their use in matters of supervision. Our difficulty lay in getting proper drivers and we are very much indebted to the caterpillar people for all the help and instructions they gave. After we had overcome to some extent the question of drivers and crews, we found that the treatment of roads by these machines does reduce supervision costs. By these machines we are able to treat longer sections and thereby to reduce the number of sectional officers and this overhead charge is one of very considerable importance. To my mind there is no doubt whatever that the use of these machines on roads not only reduces the cost of maintenance but also the cost of supervision. With regard to another of Mr. Brebner's points that you eliminate any chance of pushing any responsibility on to the contractors, well, we have not got any. There is no such thing as contractors in Assam in the ordinary sense. We have got people who call themselves contractors but they really are labour catchers. There can be no question of pushing any responsibility on to them. One thing I forgot to mention about the caterpillar tractor and the planer unit is that it reduced the unit crew. On our caterpillar tractors the driver sits on one side of the machine and from that position he can drive his tractor and control the planer blades at the same time. Instead of having one or two men on a grader and a driver on the Tractor you have one. If anybody would like to see our

figures of cost and will write to us in Shillong, we will be only too glad to let him have copies of them or any other information. Again I express our regret that we have not produced a paper. I will now ask Mr. Breadon to reply to his paper. (Loud Applause.)

Mr. G. W. D. Breadon (the Author of Paper No. 3): As regards the cost of grading I can say that the figures quoted by me in my paper are quite correct. They were taken from cost sheets. I might add that from April to the end of November 1934 the average cost is Rs. 57 per mile of road for development and Rs. 35/8 per mile for maintenance.

The rate mentioned in the paper for constructing, or to be more accurate, for reforming old roads, does not include jungle cutting, removing roots of trees and the like, but merely the cost of grader work.

2. The reasons why road grading has not advanced in the Punjab, in my opinion, are:—

(*a*) The lack of push by the Communications Board. Mr. Stubbs was the only Secretary of that Board, who took a live interest in the work and who used his influence in getting district boards to resort to grading.

(*b*) The disinclination of most district boards to depart from the contract system of working. I do not wish to give the reasons.

(*c*) The obstructive, and I should say, the destructive tactics of Board Secretaries.

(*d*) The inexperience of many district Engineers.

3. It is quite true that difficulty and delay in obtaining spare parts have had a lot to do with the dislocation of work. I myself experienced much annoyance and I have proposed a remedy in paragraph 19 of my paper. Formerly Volkarts did maintain a large spare parts department in Lahore, but they incurred very heavy losses and had to transfer all their stuff to Bombay. When more Boards take up grading I feel certain that business firms will provide good service.

4. The chief difficulty that a district engineer has to contend with is referred to in the concluding portion of paragraph 22. In the absence of suitable accounts rules, a troublesome secretary can occasion more annoyance and delay in the repairing of machinery and the settlement of accounts than the delay in obtaining spare parts. When the official Chairman is an experienced Deputy Commissioner things go smoothly in a District Board—not otherwise.

5. Grading is a work that must be done departmentally, the grading staff working directly under the orders of the district Engineer. It is a work that no contractor can do.

6. I can express no views on the soils of Madras, nor can I suggest any special method of grading roads in that Province.

PAPERS NOS. 2, 5(*a*), 5(*b*) AND 6.

Mr. D. Macfarlane, Chief Engineer, P. W. D., Punjab, in the Chair.

Chairman: Gentlemen, I think that the best arrangement for dealing with these four papers is that which we followed with regard to the last two, that is to say that as these four papers all deal more or less with the same subject, we will ask their authors Mr. Hunter, Mr. Stubbs and Mr. Adami to introduce their papers; Mr. Trevor-Jones is not here, but Mr. Stubbs will say what he has to say about this paper also, after which we will have a general discussion. So I now call on Mr. Hunter to introduce his paper if he has any remarks to make.

The following paper was then submitted for discussion:—

(*Paper No. 2.*)

THE TREND OF DEVELOPMENT IN THE UNITED PROVINCES IN THE MATTER OF IMPROVING ROAD SURFACES WITH SPECIAL REFERENCE TO RECENT EXPERIMENTS.

By C. F. Hunter, M. Inst. C.E., A.M.I.E. (India) Executive Engineer, United Provinces.

Before about 1925 little was done in the United Provinces in the matter of treating road surfaces, either with a view to rendering them comparatively dustless or to increasing their resistance to wear. About that time however the Local Government found that under increasing traffic, roads were deteriorating and the cost of maintenance rapidly going up. Most of highways in the United Provinces are very old and the foundation, judged by modern standards, inadequate. 4½ inches of large sized *kankar* is, in many cases, all that has been employed. Up to about 30 years ago the traffic consisted almost solely of slowly moving bullock carts and the light *Ekka*. Money was fairly plentiful and a 4½ inch renewal coat of *kankar* metal was applied to a mile of road as soon as the surface began to show signs of deterioration. The result of this was a gradual building up of the road crust so that 12 to 15 inches of metal was not uncommonly measured. This was sufficient for all requirements up to that time but with the advent of the motor car, conditions changed. The soft calcareous kankar which is the only material available generally in this part of India, is ill suited to resist the wear caused by the passage of fast motor vehicles and the lives of miles began to shorten to an alarming extent.

2. It was contended that if the roads were reconstructed, so as to have an adequate foundation, they would be better able to resist the traffic and so in the long run cost less to maintain. With this idea in view, schemes were prepared for digging up the existing roads entirely and reconstructing them with massive foundations. This was actually done in a few places but it was soon realized that the complete renewal of all the old metal was only so much money thrown away and that there must be a certain minimum thickness of crust that would be sufficient foundation in itself to support an improved type of wearing surface. Mr. Annette, the Road Engineer of the Bombay Improvement Trust, who had many years of experience on bituminous roads both in England and in India, expressed the opinion that 9 inches of an old stone or *kankar* road was ample foundation on which to place a bituminous wearing surface. Further, there was no absolute proof that lack of foundation was the cause of the break up of the heavy trafficked miles. It may have been due simply to the inability of water bound macadam to stand up to bullock cart traffic *plus* an increasing proportion of fast motor traffic. This theory was supported by the fact that many of the miles that showed signs of rapidly breaking up actually had a crust on them of more than 12 inches.

3. In the extensive scheme of road construction carried out in this province between 1925 and 1931 the existing crust was made use of as far as possible, being thickened, where necessary, before the bituminous surface was applied. As regards the bitumen to be employed Government had little previous experience as the work that had been done up to that time was almost negligible. There was apparently little to choose between the

Residual and the Natural asphalts. Large quantities of Trinidad Asphalt had been used satisfactorily by the Bombay Improvement Trust but against this "Spramex" and "Mexphalt" were well known in England. In America, too, it was understood that the quantity of petroleum asphalt used was many times that of the natural asphalt. In the matter of the actual treatment, Government were no better off. For this reason the re. construction programme from 1925 onwards included Premixed Asphaltic concrete; Premixed Asphaltic Macadam; Grout, and surface painting.

4. Here, perhaps a word should be said about tar. As far back as 1924, a portion of one of the most important thoroughfares in Lucknow (The Mall) was tarred over *kankar*. It was again tarred in 1925, 1927. 1929 and 1933. The road is very wide (30 to 50 feet) and the traffic is light, for bullock carts are not allowed. The census shows 86 tons per foot width per 24 hours, mostly motor cars. Under these conditions and with stone grit employed on the surface, the road has been easily maintained in excellent condition. Unfortunately, under heavy cart traffic in other places, a similar surface has failed to last and has required constant attention in order to keep it in good order. It must be remembered that at that time the necessity for a regular application of tar in order to keep the surface from becoming dead was not understood. It is further probable that the tar available was not of the quality and as suitable as that available today. Bitumen, where it had been tried had not exhibited anything like the same tendency to break up nor did it require the same constant attention. The result was that tar was considered to be inferior for surface painting work.

5. To return to the Bitumen for a while. Some of the earliest work was done with natural asphalt but unfortunately it soon appeared that this had an unfortunate shortcoming. I refer to the manner in which it softens under heat and the excellent lubricant that it then forms between the particles of aggregate. In asphaltic concrete work the surface gradually became exceedingly lumpy so that passing over it at any speed was most uncomfortable. In Grouted work, for the same reason, it worked up into ruts where it was subject to heavy concentrated bullock cart traffic. It was at first thought that this last defect was due to some weakness of the sub-grade but on cutting a section out of a defective road it was at once apparent that the trouble was the actual displacement of the asphaltic concrete crust. The same defects showed in painted surfaces, in the hot weather. They bled badly for the first year or two and required constant gritting which led to the formation of a lumpy surface. The comparative freedom of the residual bitumens from this trouble gradually led to natural asphalt failing into disfavour thus leaving the former as the most favoured preparations. Indeed, so well have they behaved on the whole that it will be found that the majority of our engineer officers prefer to work with either "Spramex" or "Soccony Asphaltum" for surface painting.

6. Grouting work with petroleum bitumen has in some places shown the tendency to rut as residual, but there are some very successful miles of this construction in existence including that on a narrow bridge on the Grand Trunk Road and carrying the traffic in and out of Delhi. A greater test you could not wish for but the defect did not appear. Apart from this, however. the satisfactory behaviour of the painted surface costing a

matter of Rs. 1-4 to Rs 1-8 per square yard compared with grout at Rs. 3-4 led to the adoption of surface treatment with the residual bitumens in practically all cases where the expense of concrete was not warranted. Emulsions of these materials have been tried but they have not been found to be economical as they do not give the same wear.

7. After the reconstruction programme referred to above had been practically completed and some experience had been gained as to the probable cost of maintenance of the various surfaces, the Chief Engineer of the United Provinces was able to review the economics of the treatments. He calculated for various surfaces the annual sum that would be required to pay off a loan equal to the cost of the wearing coat in equal instalments over a period of years equal to the life of the wearing coat at 5 per cent. interest and added to it the cost of petty repairs. This gave a basis for comparison and enabled the minimum economic life for any form of treatment to be correlated with the life of the original water bound macadam. The table at the end of this paper (Appendix I) gives the result of his investigations and the following are the conclusions that he was able to draw from them :—

(a) *Cement concrete.*—The 14 miles on which the calculations were based were originally water bound stone requiring 19·456 annas per sq. yd. for renewal on the average once in 5 years and an annual expenditure on ordinary maintenance of 0·997 annas per sq. yd. This gave a total annual cost of 5·491 annas per sq. yd., therefore to be economic, the life of concrete costing 92·832 annas and assuming annual maintenance of 0·136 annas per sq. yd., if wholly renewed, would have to be over 40 years. The life of the macadam replaced by concrete was actually nothing like 5 years. In some cases it was one year and at the outside three years or on the average 2 years. The fact that these miles were not renewed for 5 years means that the road was passable for 2 years and impassable for 3 years and it was for this very reason that concrete was tried. A reference to the statement will show that for a two year life and three year life of a water bound road, the economic life of concrete is twelve and eighteen years respectively. Such a length of life is well within the bounds of possibility, as some concrete on the Kathgodam Nainital road has already been down fifteen years.

A point to be remembered in this analysis is that it is based on the assumption that the whole of the concrete would have to be renewed at the end of twelve or eighteen years, but in all probability this would not be the case, and it would only be necessary to lay a 3 inch coat or some other form of surfacing, in which case the required or economic life could be considerably less. In the absence of sufficient data, however, it is preferable to assume that the whole thickness will have to be renewed. The conclusion is that for a waterbound road, the annual maintenance cost of which is over 6 annas per sq. yd., it is more economical to use cement concrete.

(b) *Premix.*—The calculation was based on 6 miles for which we estimated that we should require average renewal at 16·892 annas per sq. yd. once in 4 years and yearly maintenance at 0·558 annas per sq. yd., giving annual cost of 5·322 annas per sq. yd. To be economical, premix costing 78 713 annas per sq. yd. would have to have a very long life. Even for a three year life of water bound, the life of premix, assuming a reseal every 5 years at 4·145 annas and yearly maintenance at 0·113 annas per sq. yd.

would have to be 21 years to be economic. For a two year life of water bound, it would have to be 12 years. It is out of question to put the life of premix at 21 years without renewal whilst if the life of water bound macadam is only 2 years, it is doubtful whether premix would stand the traffic and it would be preferable to lay concrete at slightly higher cost.

(c) *Grout. T. R. A. and Mexphalt.*—The calculations were based on 12 miles of T. R. A. and 18 of Mexphalt. The estimated cost of renewal was 15·477 and 14·979 annas per square yard once in 5 years with annual maintenance at 0·721 and ·764 annas per sq. yd. respectively. The annual cost worked out to 4·296 and 4·224 annas per sq. yard respectively. To be economic the life of grout T. R. A. and Mexphalt costing 52·128 and 45·582 annas per sq. yard for renewal and ·140 and ·166 annas per sq. yard for maintenance respectively, would have to be excessive, but if the life of water bound is taken as four or three years the corresponding economic life would have to be as follows:—

Water Bound.	Reseal every four years.		Reseal every three years.	
	T. R. A.	Mexphalt.	T. R. A.	Mexphalt.
4	24	20	29	24
3	15	13	16	14

From the above table it will be seen that the longer the period between repaints, the shorter the necessary economic life. It is very doubtful whether grout will last over 20 years and it remains to be seen if it lasts 16 years, and if it does, it may be workable substitute for macadam costing for maintenance between six and eight annas per sq. yd.

(d) *Paint.*—Calculations were worked out on (i) 8 miles which had received a second coat of paint and (ii) 11 miles of painted road between Agra and Mainpuri. In the former case the cost of resurfacing, yearly maintenance and average life was estimated at 17·928 annas per sq. yd.; 0·831 annas and 6 years. This resulted in an annual cost of 4·363 annas per square yard. The actual cost of water bound macadam worked out to 20·523, first coat of paint to 8·595 and the second coat to 4·785 annas per sq. yd. Here again the question of the period of repaint has to be taken into consideration; the actual average worked out for the period between 1st and 2nd coats came to 2½ years, but there were many instances where the paint has been down 3 years without a second coat, therefore it seemed safe to fix the period between 1st and 2nd coats as 2 years and between 2nd and 3rd or subsequent coats as 3 years, in which case the economic life would have to be somewhere between 14 and 17 years, whilst if the period between 1st and 2nd subsequent coats of paint was taken as 3 years, the economic life would have to be somewhere between 15 and 18 years, compared with 6 year life of water bound. A point to note however was the cost of water bound resurfacing which had gone from 17·928 to 20·553, and if the latter figure was taken in calculating the annual cost of water bound then a 14-year

life of the painted mile would have been definitely economical, and there was no reason why painted miles under moderate to light traffic should not last this period. In the second case our estimate of requirements allows 14·321 for renewals 0·747 for petty repairs and an average life 4 years. The actual cost of resurfacing worked out to 16·524, first coat paint to 7·729 and second coat to 4·162 annas per square yard; and allowing a period of 2 years between the first and second coats and 3 years between second and subsequent coats, the economic life could be as low as 11 years.

Summing up the results as far as information was available at that time, it appeared that:—

(a) When the life of a water bound road was only two or three years and the annual maintenance over 8 annas per sq. yd. it was economical to lay concrete.

(b) When the life of a water bound road was three to four years and the annual charge between 6 to 8 annas per sq. yd. it might be economical to lay bitumen grout.

(c) When the life of a water bound road was 5 to 6 years and the annual cost between 4 and 6 annas per sq. yard it would be economical to paint the miles.

8. During the period that I have referred to above we had no reliable returns of traffic to enable us to form a correct estimate of the load per foot width that surfaces were being called upon to carry and there is no doubt that in some cases they were called upon to stand more than they were capable of.

Since 1932 we have been taking a regular census at all important points on our communications and it has been possible to gain some idea as to what a painted surface executed with the good materials is capable of standing. We have a few miles standing 150 tons of bullock carts per foot of width per 24 hours. Other traffic is neglected as not appreciable effecting the wear. The miles in question are mostly "Spramex" either alone or in conjunction with other materials. The above figures are no doubt exceptional. From my personal experience I should fix 80 tons per foot width per 24 hours as the limit that can safely be carried by this form of surface, particularly where bullock carts fitted with narrow iron tyres are employed. It has been calculated that the load under the narrow iron tyres of a bullock cart loaded with bricks may be as much as 8 tons per linear inch and this combined with the twisting action on the wheels, due to the manner in which these carts progress, gives a set of conditions that it is very hard for a road surface to stand up to for any length of time. In this connection it must be remarked that when loaded bullock carts use one side of the road only as in passing from brick kilns to a town, this fact must be allowed for in calculating the intensity.

It is difficult to see how the gradual development of brittleness in tar is to be combated. It has been stated that in America the use of tar is dying out for this very reason. It has been suggested that provided the tar is kept from contact with the air, the process should not take place and that an application of bitumen over a tarred surface should have the effect of sealing it in such a manner as to make it impossible. It is certainly true that in certain places where bitumen has been applied over

tar, as two coat work, in the past, defects that might be attributable to the hardening of the tar have not developed and the roads have stood remarkably well. This, however, is not conclusive for subsequent work, carried out to the same specification—Experiment (*h*) (i)—has not shown the same degree of success.

9. With the assistance of the Government of India the following experimental work with tar has been carried out in the Lucknow and Cawnpore divisions, with the object of again trying tar, either by itself or in combination with bitumen, and of comparing its behaviour with that of work carried out in the latter material only. In Lucknow various premixed carpets have been tried under probably the worst conditions that are to be found in the vicinity, for the road carries intense brick kiln traffic. This, according to our traffic census is about 144 tons per foot width of travelling surface per 24 hours but as the road is 16 feet wide nearly all the loaded carts use one side only. If they all did this the figure of the intensity would rise to about 220 tons per foot. It was realized, before the work was started that the traffic was probably too heavy for any thing but concrete and the representatives of the Burma Shell Co. did not like the idea of putting their material down under such destructive conditions. It was thought, however, that as a test of relative durability, the experiment should be of considerable value.

The following is a description of the various experiments:—

(*a*) *1½ inch premixed macadam carpets with both good stone and good kankar as an aggregate and with both No. 1 and No. 2 Shalimar Tar. In small lengths a filler of 25 per cent. of coal dust was also added.*—All this work was laid to a specification that had been used in the Punjab but none of it was a success. The surface began to disintegrate practically as soon as the work was finished. Indeed in the case of work done with No. 1 and thinner tar, the disintegration was so rapid that no attempt was made to seal the surface or to save it in any way. It was dug up and water bound put down in its place. It may be mentioned that it was not observed that the presence of the coal dust filler made the slightest difference. The specification to which this was carried out included the laying of the premixed material on the loose recambered surface of the old road and also the use of copious water during consolidation. It is believed that both these provisions mitigate the chance of a properly consolidated carpet being obtained. In the first place mud and fine material work up from the bottom and soil the tarred surfaces of the aggregate in such a manner as to prevent proper cohesion. In the second, the use of water appears to have a detrimental effect upon the tar. The former conclusion is supported by the fact that in a short length where the old surface was consolidated by mistake the result appeared to be better; the latter is supported by the fact, that, on digging up a defective portion of the carpet subsequently, the subgrade showed distinct traces of what appeared to be oil.

(*b*) *A 2½ inch carpet of stone mixed with No. 2 tar to a specification supplied by the Shalimar Company.*—The stone used in this case was 2 inch Gneiss in the under coat and ½ inch to 1¼ inches of the same material in the top coat. It may be mentioned that this variety of stone was used in all the subsequent experiments. The tar was No. 2 Shalimar, 2½ lbs. being used per cubic foot of the coarse material and 3 lbs. in the case of fine. After mixing, which was done in a simple form of rotary hand mixer, the material was matured in bulk for 10 days though the

company subsequently (and too late) asked that it be laid hot. After maturing it was laid and rolled in the usual manner. The original instructions as to sealing this were that it should be done after two months but signs of the surface becoming loose became apparent and, at the suggestion of the Executive Engineer, the seal was applied after 3 weeks only. This seal was formed by applying ·23 gallons of No. 2 tar per square yard and gritting with ¾ cubic foot of ¼ inch to 5/8 inch chips. After sealing, the surface appeared to harden satisfactorily but at the time of writing (5 months after completion) signs of breaking up are appearing and it is doubtful whether the road will last another six months.

(c) *A 4½ inch Shelmacadam carpet to the specification of the Burma Shell Co.*—Here the under coat was of 1½ to 2 inch metal. The bitumen mixture was composed of 2 drums of "shelmac" to 4 of "Mexphalt" and the material was laid hot straight from the machine mixer, 10 lbs. of bitumen being used to coat 3·75 cubic feet of ballast. The seal coat was laid immediately ⅜ inch to ½ inch chips being employed with 12 lbs. of bitumen mixture to each 3·75 cubic feet of stone. The composition of the mixture was the same as above. The behaviour of the carpet showed that the Company's misgivings were well founded for signs of disintegration appeared six weeks after the work was completed and at the present time the process is complete.

(d) *A 3 inch carpet of "shelcrete" to the specification of the Burma Shell Co.*—In this treatment no seal was employed but an effort was made to obtain as compact a mass as possible by filling the voids of the large aggregate with coarse sand which was obtained from Badausa. Two cubic feet of coarse aggregate were used to one of fine, and with each batch of 3 cubic feet was mixed 15 to 16 lbs. of a bitumen mixture composed of 1 drum of "shelmac" and two drums of "Mexphalt" (20/30 penetration). A machine mixer was employed and as advised by the firm, the coarse aggregate was coated first with a portion of the bitumen after which the fine aggregate and the balance of the bitumen were added. The mixture was laid direct from the mixer as before and after completion the surface presented a very compact appearance. At the present time there are no signs of disintegration though the work has been down 4 months.

(e) *1½ inches of "Shelsheet" to the specification of the Burma Shell Company.*—This specification was put forward by the company as a substitute for cheap kankar surface and not as being capable of standing very heavy traffic. It was accordingly not tried next to the surface previously mentioned but where the road was subject to comparatively light traffic and beyond the limit of the brick kilns. The situation is representative of hundreds of miles of main roads to be found in the United Provinces. The actual intensity of traffic is only 40 tons per foot width of travelling surface and such as a tar painted surface would easily stand.

The process aims at obtaining the most compact mixture of aggregates possible in this case, using the most economical materials available, the following material was recommended and employed:—

¼ inch to ½ inch stone chips	2	cubic feet.
Badausa sand previously mentioned	1	cubic feet.
Fine micaceous sand from the local river (the Gumti)	1	,,

With this was used 26 lbs. of bitumen mixture (2 "Mexphalt" to 1 "Shelmac") the same precautions being taken as in the case of the "Shelcrete" to ensure that all the aggregate was properly coated. The material was laid hot, the old kankar surface having been given a tacking coat of Fuel Oil and residual bitumen the day before. The length laid was only about 100 feet as the monsoon set in and stopped further work. The small amount of work done has probably raised the cost somewhat. The surface is standing excellently. At the time of writing it has been down about four months.

The cost of these carpets is given in Appendix II.

10. In Cawnpore the experiments were confined to surface painting either with tar alone or in combination with bitumen. In one of the miles one half was treated with tar to a specification that had been used in the Punjab and the other half to a specification that had been recommended from Peshawar. In a second mile combinations of tar and bitumen were tried, both in separate coats and together in one coat. A third mile was tarred using a filler of coal dust in various proportions in the second coat, as this combination is known to have been used successfully in France. Further, with a view to trying a cheap gritting material, cinders were used in some lengths so as to be able to compare with those gritted with the more usual stone chips. In each case the surface was first renewed by scarifying, recambering and spreading a thin coat of new metal, 12,000 c.ft. was used for a mile of 12 foot road and 16,000 for a mile of 16 foot. This is a form of cheap renewal that has been advocated by the Punjab.

11. The following is a description of the experiments in some detail;—

(*i*) *Painting to Lahore and Peshawar specifications.*—The Lahore specification for tarring allows only one fifth of a gallon per sq. yard of Tar No. 2 in the initial coat whilst the Peshawar allows three-tenths of Tar No. 1. It was found difficult to use the smaller quantity. As has been the experience in other parts of this province, the quantity of material that you use depends on the cleaning. Where a friable material has been used for blinding in the water bound coat, the operation of cleaning removes the same to a considerable depth below the surface of the metal and you cannot get on less than about one quarter of a gallon per sq. yard. In this case it was found to be impossible to get on less than 0·26 gallon. Trouble was also experienced owing to the blinding material used having been kankar *bajri*. It has been found elsewhere that the very fine dust resulting from the pulverizing of that material gives rise to trouble, not only at the time of pouring but also after the work has been finished. It prevents the proper adhesion of the tar to the stone. At one place in the Province where both kankar bajri and Delhi *moorum* were used in adjacent work the difference in behaviour was very marked.

The Executive Engineer in charge of the work also recommended that an interval of about an hour should be allowed to elapse between the pouring of the tar and the subsequent gritting as he was of the opinion that this would allow penetration of the former into the road and also bring about a general evening up of the thickness of the coat. The Traffic which this work has to stand is light, being only 37 tons per foot of width per 24 hours.

Both the experiments have worn satisfactorily but the condition of the surface indicates that a second coat of tar is now due (about 9 months after the first). This is now being given. The larger quantity of No. 1

tar used in the Peshawar specification certainly appears to give good penetration for an examination showed that this had occurred to a depth of ¼ inch below the original depth to which the surface had been cleaned. It does not, however, make such a good wearing surface. It remains to be seen how the two experiments behave after the application of the second coat.

(*g*) *A mixture of 15 per cent. Mexphalt of 20/30 penetration and 85 per cent. of No. 1 Tar.*—The application calls for no special comment. 0·33 gallons of the mixture were used per sq. yard and 0·3 of a cubic foot of chips.

The mixing of the Mexphalt gave body to the Tar and the surface is wearing well though at the present time (about 9 months after completion) it is in need of a second coat. The mixture appeared to give a better wearing surface than was obtained by the application of a similar quantity of tar No. 1 only as described in experiment (*f*). It appears, therefore, that a suitable combination would be Tar No. 1 in the first coat on account of its superior penetrating qualities and the above mixture in the second, on account of the superior wearing surface that it appears to give.

(*h*) *An application of Bitumen over a coat of Tar.*—The application of two separate coats in this manner lasted very well in Bareilly. Three different combinations were tried:—

(*i*) 0·5 gallon of "Spramex" over 0·3 gallon of No. 1 Tar, the application being made after 24 hours. This was the Bareilly specification referred to above.

(*ii*) 0·25 gallon of "Spramex" over 0·2 gallon of tar with an interval of 10 days under traffic.

(*iii*) 0·2 gallon of "Shelmac" over 0·3 gallon of No. 1 Tar with a 10 days interval.

Each of the above operations consisted in the application of two separate coats in each coat the same quantity of grit was used *i.e.*, 0·3 cubic foot per sq. yard.

Two months after completion it was noted that in all three cases the surface cracked, apparently due to the material on the surface having hardened whilst the layer of tar underneath was still soft. There was also a tendency for patches to come clean off taking part of the stone coat with them. The defects were less noticeable in (*ii*) where not only was less material used but an interval allowed to elapse between the application of the two coats. In (*iii*) the defects were very marked indeed. It seems certain that if work of this kind is to be done at all the tar coat must be allowed to harden to a desirable degree before the bitumen coat is applied though a smooth surface to the bottom layer should be avoided.

The road is 16 feet wide and carries a traffic of 115 tons per foot width per 24 hours.

At the present time the surface of Nos. (*i*) and (*ii*) is much better than one was led to expect from its early behaviour as it has hardened up and is expected to last for another year or so. No. (*iii*), in which the "Shelmac" was used, is breaking up. The Executive Engineer in charge is of opinion, however, that the treatment would be a success if a couple of months were allowed to elapse between the applications so as to avoid the presence of a hard bitumen surface on a comparatively soft underlayer of tar.

(i) *Two coats of Tar, the first being of tar only and the second of tar with a filler of coal dust in various proportions.*—A cheaply renewed road was operated on as before but in this case it was opened to traffic for six months before being treated in order to allow the metal to stabilise. The first coat of No. 1 Tar was at the rate of 0·29 gallon per sq. yard with 0·2 c.ft. of grit. This was allowed to remain under traffic for about a year when the second coat containing the filler was applied. The same tar was used, the amount of filler varying from 10 to 33 per cent. Further, in some cases cinders were used for gritting instead of stone chips. The coal dust was passed through a 10 by 10 mesh screen and mixed with the tar in the boiler. A power driven mechanical mixer was employed and it was observed that the coal dust tended to settle unless continually agitated.

The road on which this was tried was close to that of experiment (f), the traffic being the same, *i.e.*, 37 tons per foot width of travelling surface.

At the present time the work has been down about six months and it is not possible to detect any difference between the portion in which stone chips were used for gritting and that in which cinders were used. Cinders at Rs. 5 per hundred cubic feet appear to be standing as well as stone chips at Rs 30. The use of coal dust causes a distinct improvement in the adhesiveness and viscosity of the tar. It was found to hold more grit than the neat material.

The cost of these treatments is given in Appendix III.

12. From the results of these experiments it would appear that as far as carpets are concerned and for sheer ability to stand up to intensive cart traffic the most durable material of those tried is "Shelcrete". Next in order come the "Shalmac" tar carpet, "Shelmacadam"; and finally ordinary premixed macadam laid to the Punjab specification. Whether carpets will ever be developed which will compare economically with concrete under bullock cart traffic remains to be seen. It certainly appears that the most compact will be the most durable and the cost of the aggregate will then be much the same as if a cement matrix was employed. The difference in cost will be small. It remains to be seen what ratio the lives will bear to one another.

For surface work it is a little early to draw conclusions but No. 1 Tar appears to be indicated in the initial coat on account of its superior penetrating properties. A second coat of 85 per cent. of tar No. 1 and 15 per cent. of "Mexphalt" would appear to make a good combination. In any case the first coat should be allowed ample time to harden. On the question of the use of coal dust as a filler and of cinders as a gritting material it is a little early to express an opinion. Finally it must be remembered that some of this experimental work has not been through extreme heat and cold combined with traffic. This is one of the greatest tests that can be applied to surfaces of the nature of those with which this note deals

Appendix I.

Lives of various types of improved surface equivalent to those of water bound macadam.

Cost of wearing coat.	Cost of P. R.	Life in years.	Annual cost 5 per cent. interest.	Materials used in reconstruction.	Cost of wearing coat.	Cost of P. R.	Equivalent economic life in years.	First paint. Cost.	First paint. Life in years.	Second coat or seal coat. Cost.	Second coat or seal coat. Life in years.	Annual cost 5 per cent. interest.	Remarks.
Annas per sq. yd.	Annas per sq. yd.		Annas per sq. yd.		Annas per sq. yd.	Annas per sq. yd.		Annas per sq. yd.		Annas per sq. yd.		Annas per sq. yd.	
19·456	0·997	5	*5·491*	Cement concrete.	92·832	0·136	..	..	..	..	..	..	
		4	6·484	..	..	..	27	..	..	..	..	6·149	
		3	8·137	..	..	..	18	..	..	..	..	8·120	
		2	11·464	..	..	..	12	..	..	..	..	11·462	
16·892	0·558	4	*5·322*	Premix	73·713	0·113	..	..	..	4·145	5	..	
		3	6·757	..	..	..	21	..	..	4·145	5	6·746	
		2	9·656	..	..	..	12	..	..	4·145	5	9·621	
15·477	0·721	5	*4·296*	Grout T. R. A.	52·128	0·140	..	..	..	4·145	4	..	
		4	5·086	..	..	..	24	..	..	4·145	4	5·062	
							29	..	..	4·145	3	5·101	
		3	6·401	..	..	..	15	..	..	4·145	4	6·418	
							16	..	..	4·145	3	6·405	
14·979	0·764	5	*4·224*	Grout Mexphalt	45·582	0·166	32	..	..	4·145	5	4·207	
							..	..	..	4·145	5	..	
		4	4·988	..	..	..	20	..	..	4·145	4	4·082	
							24	..	..	4·145	3	4·969	
		3	6·261	..	..	..	13	..	..	4·145	4	6·258	
							14	..	..	4·145	3	6·245	
14·321	0·747	4	*4·786*	Paint Spramex.	16·524	0·340	11	7·729	2	4·162	3	4·328	11 miles between Agra and Mainpuri.
17·928	0·831	6	*4·363*	Paint Spramex.	20·553	0·457	14	8·595	2	4·785	3	4·690	
					..	..	15	8·595	3	4·785	3	4·466	

Appendix II.

Detail of cost.

(Carpets.)

Carpets.	Cost of material in annas per sq. yd.	Cost of laying in annas per sq. yd.	Miscellaneous charges in annas per sq. yd.	Total cost per sq. yd.	Remarks.
				Rs. a. p.	
(a) I.—1½″ water bound stone premixed with tar No. 1 . . .	11·1	5·2	2·4	1 2 9	
II.—1½″ water bound stone premixed with tar No. 1 and with filler . . .	11·5	5·3	2·4	1 3 2	
III.—1½″ water bound stone premixed with tar No. II . .	11·3	5·3	2·4	1 8 0	
IV.—1½″ water bound kankar premix with tar No. 1 . .	11·4	6·0	1·8	1 3 3	
V.—1½″ water bound kankar premix with tar No. 1 and with filler	11·7	5·7	1·7	1 3 0	
VI.—1½″ water bound kankar premix with tar No. II . .	11·7	5·8	1·8	1 3 4	
(b) VII.—2½″ premix carpet to Shalimar specification . . .	16·6	7·1	1·1	1 14 10	
(c) VIII.—4″ Shell macadam	36·7	5·7	..	2 10 6	
(d) IX.—3″ Shelcrete . .	38·0	8·2	..	2 14 3	
(e) X.—1½″ Shelsheet . .	43·9	6·1	..	3 2 0	

Appendix III.

Costs.

(Surface Treatment.)

Experiment.	Nature of Experiment.	Cost per yard.
		Rs. a. p.
(*f*)	Lahore specifications of Tar Painting only 1st coat with Tar No. 2 at ·26 gallons per sq. yard was given in March 1934	0 5 3·56
(*f*)	Peshawar Specification of Tar painting only 1st coat with Tar No. 1 at 0·31 gallons per sq. yard has been given in March 1934	0 5 6·6
(*g*)	Painting with a mixture of Tar No. 1 and Mexphalt in the ratio of 85 and 15 at 0·33 gallon per sq. yard . .	0 5 6
(*h*)	1st coat of Tar No. 1 at 0·32 per sq. yard 2nd coat Spramex at 0·5 gallons per sq. yard (Bareilly Specification)	1 0 4·0
(*h*)	1st coat of Tar No. 1 at 0·2 gallons 2nd coat spramex at 0·25 gallon per sq. yard	0 9 4
(*h*)	1st Coat Tar No. 2 at 0·2 gallons per sq. yard . .	0 8 10
	2nd coat Shelmac at 0·2 gallons per sq. yard.	
(*i*)	1st coat tar No. II at 0·29 gallon per sq. yd. and stone chips	0 4 10·04
	Second coat with Tar No. I and II mixed with various proportions of coal dust and blinded with grit and cinders as detailed below :—	
(*i*)	Tar No. II with 10 per cent. Coal Dust and cinders .	0 2 10·57
(*i*)	Tar No. II with 10 per cent. coal dust and stone chips .	0 4 4·5
(*i*)	Tar No. 1 with 20 per cent. coal dust and cinders . .	0 2 8·07
(*i*)	Tar No. 1 with 20 per cent. coal dust and stone chips .	0 4 1·90
(*i*)	Tar No. 1 with 25 per cent. coal dust and cinders . .	0 2 9·24
(*i*)	Tar No. 1 with 25 per cent. coal dust and stone chips .	0 4 3·07
(*i*)	Tar No. 1 with 35 per cent. coal dust and cinders . .	0 2 8·21
(*i*)	Tar No. 1 with 33 per cent. coal dust and stone chips .	0 4 2·04

Mr. C. F. Hunter (the Author): Mr. Chairman and gentlemen: Paper No. 2 describes the general trend of development in the United Provinces and it gives a description of some of our more recent experimental work. It appears to me that one cannot have greater assurance of the soundness of a particular line of action than to find that a similar one has been adopted elsewhere to meet similar conditions. If, on the other hand, it is found that a different line of development has been followed, then much will probably be learnt by studying the reason for the difference. I have, therefore, described as simply as possible the factors which have led us to adopt mainly surface painting for our roads and that with petroleum bitumen. Though most of us here this morning are engineers yet unfortunately we are also men and one of the attributes of the human race is a tendency to act rather like sheep. This is, I think, one of the things to guard against. It is so easy and natural at times to follow a certain treatment or line of action because it is known to have given you satisfaction in another part of your own province with the result that we may be led to develop on our own lines when there are others which are just as good, perhaps better. One of the main objects therefore in writing this paper is to elicit the experience of engineers in other parts of India where conditions may be similar to those with which we have to contend in the United Provinces. Before I conclude, there are two points which I should like to make clear. As regards the carpets which you will find dealt with in paragraph 9 of the paper, on my way here I came over that stretch of road and excluding the Shelsheet which is not laid under the same conditions, the only carpet which has given satisfaction is the Shelcrete. This was put down some time in the hot weather; so that it has been down for about six months now under the heaviest traffic which we can find round Lucknow. The second point is that unfortunately it has not yet been used to any great extent and the costs that I have given are only those of short experimental lengths. They may serve to give some idea as to the relative cost for the different methods of construction but it must not be taken that work in quantities would cost in the same proportion. I daresay you spend as much as 20 per cent less in long lengths. You all know how much time is wasted in getting a move on in the initial stages. Our lengths were very short. In one case it was one furlong and in the other case even half a furlong.

The following papers were then submitted for discussion.

[*Paper No. 5 (a).*]

Being a Paper* Contributed for the 1934 International Road Congress.

Progress made in the use of tar and bitumen in the Punjab since the last International Road Congress in Washington in October 1930.

By

S. G. Stubbs, O.B.E., I.S.E., Officiating Road Engineer with the Government of India.

Maintenance of provincial metalled roads in the Punjab.—The area of the Punjab is approximately one hundred thousand square miles and its population is 23½ millions. Apart from the needs of motor transport which are great adequate facilities for the transportation of agricultural produce to markets by means of bullock carts are of still greater importance, as the prosperity of the province is dependent to a very large extent on the prosperity of the agriculturist. The Punjab has long recognised this important fact and also fully realises that under the combined action of motor and bullock cart traffic plain water-bound is the most expensive type of surface to maintain and that therefore the improvement of such surfaces to render them more suitable to the present day traffic conditions is an economic necessity.

2. A comprehensive programme has been framed with the object of surface painting or otherwise improving the entire milage of provincial metalled roads within the next few years. There are some 3,850 miles of metalled roads in the province of which 2,710 are provincial (that is under the direct control of the local Government) and 1,140 miles are maintained by District Boards. In addition to this, there are about 6,000 miles of earth roads in motorable condition. This paper deals with the 2,710 miles of provincial metalled roads. Of this milage, 1,030 are still water-bound macadam, 1,600 surface painted, 70 miles grouted with bitumen or a mixture of tar and pitch and 10 miles are of premix work, referred to later on. In many parts of the Punjab stone metal is very expensive ranging as high as Rs. 40 per 100 c. ft., and a very significant feature of the grouted work is that in about 10 miles out of the 70, the aggregate consisted of brick metal broken from hard burnt bricks, the results obtained being very satisfactory. Though grouting has on the whole proved very satisfactory the initial cost, even using brick ballast as aggregate, was far too high to permit of improvement of road surfaces in this way to any great extent. A very much cheaper method had to be devised, and up to the present time the main treatment adopted for the improvement of water-bound surfaces was and is still surface painting with tar, and this has produced surprisingly good results even under really heavy (for India) traffic conditions.

3. Tarring of roads was first started in the Punjab about 1914 far more with the object of reducing the dust nuisance than anything else, and it was not until about ten years later that it began to be realised that the greatest

*Note.—The paper has been somewhat curtailed and altered by the elimination of material not necessary for a body of Engineers in India.

benefit derived from tarring was the reduction of maintenance costs. It was found even on roads carrying very heavy traffic that once a road was tarred, the underlying metal appeared to last indefinitely. The following few examples appear to justify this conclusion.

Name of road.	Date of renewal.	Date of first tarring.	Present condition.
1. Mall, Lahore—			
Part I	1915-16	Shortly afterwards.	Paint coat applied annually. No sign of metal wearing.
Part II	1916-17		
2. G. T. Road Miles 313-314 ..	1913-14	1916-17	Do.
3. Mayo Road	1925	1925	Do.
4. McLeod Road	1925	1925	Do.

NOTE.—Roads Nos. 3 and 4 carry exceedingly heavy bullock cart traffic in addition to heavy motor traffic and both lead to the Lahore Railway Station.

4. Though it was fully recognised even as early as 1924 that tarring done on an extensive scale would result in a large saving on the maintenance of metalled roads, tarring could only be carried out to a very limited extent on account of the lack of funds. This was due to the fact that the general practice was to renew with 4½ inches or nearly 4½ inches of metal and to apply a coat of tar every year after the initial application had been made. Thus, if the average number of miles to be renewed every year were not reduced, and this was impossible without lowering the standard of the surface, the milage of new tarring that could be undertaken annually became less and less unless bigger road grants were forthcoming and as this was most unlikely the very item of work, namely tarring, that was so necessary in order to reduce the maintenance expenditure on metalled roads could only be carried out on a very modest scale. In the year 1927-28 there were only 73 miles improved water-bound surface (including tar painting) out of a total of 2,150 miles and it happened that at that time there was a very large increase in motor traffic with the result that the surfaces of metalled roads were being torn to pieces. It therefore seemed clear that unless the cost of renewals could be considerably reduced in order to permit of more extensive tarring, metalled roads would soon become impassable. Extensive experiments were carried out from about 1926 to 1930 and as the result of these it was definitely established that, if tarring was to be done, the amount of the new metal used in the past for renewal was excessive and that the quantity required for a mile 12 feet wide could be reduced from 24,000 c. ft. to a figure between 6,000 c. ft. to 12,000 c. ft. This meant that the cost of renewals could be reduced by 50 to 75 per cent. As a result of the introduction of a very much cheaper method of renewals called "Cheap renewals*" and the consequent large savings that accrued, the milage of the improved water-bound surface in the province was increased from 73 in 1927-28 to 1,407 in 1932-33 not only without any addition to the total expenditure, but during the last two financial years, there was actually a drop in expenditure. If funds at the rate of about Rs. 1,500 a mile per annum continue to be provided, it is expected that in 1936-37 the entire water-bound

* "*Indian Roads*", March 1933, page 3 and Appendix I, page 10.

metalled milage of provincial roads will be improved and that the cost of maintenance will then drop to Rs. 1,096 per mile per annum (see Appendix I). This figure of Rs. 1,096 per mile per annum is based on the assumption that a coat of tar will be applied every year. Even though tarring conserves the metal and thereby reduces the maintenance costs to a very large extent, nevertheless the subsequent annual coats of tar involve a heavy recurring expenditure. To what extent such expenditure can be reduced by making the coats biennial instead of annual has not been definitely determined. It is found with the very high summer temperatures prevailing in the Punjab that tar deteriorates to a very great extent by evaporation of the lighter oils and oxidisation than by the action of traffic. There is therefore a measure of risk in eking out a tar paint coat for more than a year, more especially if the traffic includes a large number of loaded bullock carts shod with iron tyres. Though the atmospheric influence on bitumen is negligible in comparison with tar, it is found from experience in the Punjab that it is very liable to peel off if applied as a paint coat direct on metal, but very satisfactory results have been obtained with bitumen painting on a previously tarred surface provided that the latter is moderately fresh. Experience gained so far seems to point to the conclusion that if a suitable grade of bitumen were applied as a third or perhaps even as a second coat, it may not be necessary to paint the road surfaces annually. Hitherto the practice has been to apply bitumen at the rate of 1/5 to 1/6 of a gallon per sq. yard even for subsequent coats as against an application of 1/10 of a gallon per square yard generally adopted in the case of tar. This would make bitumen painting about 70 to 80 per cent. more expensive than tar painting and this is probably one of the reasons why bitumen has not been used to any appreciable extent even for subsequent coats.

5. It is understood that the tendency of modern practice in England is to apply bitumen even for hot applications as thin as possible as it considerably reduces the possibility of the formation of corrugations. specially if the coating of bitumen is covered with the maximum quantity of chips that can be held in position. Experiments carried out by the writer about 18 months ago on about 3 miles of road show that it is quite possible to spray hot bitumen (100 penetration) at the rate of 1/10 of a gallon per square yard, and that this quantity of bitumen will quite effectively hold in position 1/4 inch thickness of chippings. This means that it is possible to lay a subsequent coat of bitumen at more or less the same cost as a coat of tar. Therefore if we can continue to get a life of about 18 months with such an application of bitumen. it follows that the cost of maintenance will be reduced to about Rs. 850 a mile per annum. The extensive experiments with surface applications of bitumen show that, even when the bitumen (100 penetration) is applied in the hot weather. there is an immediate and a very great drop in temperature as soon as the bitumen touches the road, and as at this reduced temperature bitumen has a limited covering and penetrating capacity neither the surface of the road nor the surface of the chippings is completely covered, as the bitumen at a comparatively low temperature is unable to penetrate into the tiny crevices and irregularities. In other words the "wetting power" of 100 penetration bitumen even at sun temperatures during the summer is very much less than a material like tar. Therefore adhesion is not as great. Besides this 100 penetration bitumen softens considerably at high temperatures and therefore the chips are not held

sufficiently firmly in position and crushing takes place not only of the chips themselves but of the underlying metalled surface. This results in the formation of very fine particles which is still more difficult to "wet" and therefore the surfacing becomes too dry and is very likely to disintegrate. It therefore seems clear that we require a surfacing material that has not only considerable "wetting power" but it must also have the capacity of hardening up soon after the chips are completely absorbed and of remaining hard even at sun temperatures during the summer months. Tar possesses these properties in a very marked degree, but unfortunately and as already stated tar is considerably influenced by the atmosphere and eventually becomes too brittle unless covered with fresh applications.

6. In order to ascertain the most suitable material for subsequent applications, experiments have been and are being carried out with (*a*) cut backs and (*b*) tar bitumen mixes. In both cases a hard grade of bitumen (20-30 penetration) is being used and for (*b*) a tar complying with B. S. S. No. 1 Tests carried out seem to point to the conclusion that the quantity of bitumen in tar bitumen mixes should not exceed 30 per cent. and that the most satisfactory mixes are obtained by using a low viscosity tar and a hard grade bitumen. In the process of mixing, the tar and bitumen are heated separately, the bitumen being first heated to 350°F. to ensure thorough melting and then allowed to cool to 270°F., and the tar to about 200°F., so when the two are mixed the resultant temperature is 250°F. At no stage should the temperature of the tar exceed 250°F.; it is therefore advisable to add bitumen to the tar gradually.

7. A certain number of the Punjab engineers believe, and the suppliers of tar claim, that after a certain number of annual applications, say four or five, it will only be necessary to paint road surfaces once every other year. If this is so, so much the better, as tar is an indigenous product, it is therefore in the interests of the country that it should be used as far as possible provided there is no wasteful expenditure. However, whatever is used for subsequent coats, tar, bitumen or a mixture of the two, there is ample evidence to show that eventually, say in three or four years, surface painting need not be done annually and the cost of painting roads with either bitumen or a mixture of tar and bitumen will not be a great deal more than that of tar painting. It is therefore not unreasonable to predict that the cost of maintenance of metalled roads in the Punjab maintained by the P. W. D. may come down to about Rs. 750 per mile per annum.

Water-bound premix.

8. Though the results obtained with "cheap renewals" followed by surface applications of tar have been very satisfactory, it was felt that still better results could be obtained by incorporating a certain quantity of tar in the body of the surface, and as a result of continual experimenting with this object in view a specification called "Water-bound Premix" has been devised and introduced. The name is derived from the fact that even though the aggregate is coated with tar or bitumen, water is used during consolidation. Experience during the last 60 or 70 years has shown that on roads carrying only bullock cart traffic there is no better type of low cost surface than plain water-bound

macadam, provided the metal has sufficient powers of resistance against crushing. The object of this specification is therefore to derive all the advantages of water-bound macadam which are considerable and a great many of premix work and thus to provide for both bullock carts and motor traffic at a minimum cost. The process broadly consists of laying two layers of pre-coated aggregate, one consisting of 2 inches of pre-coated metal (from ¾ inch to 1½ inch gauge) and coated with 2½ per cent. of binder; and the second layer of about a ¾ inch layer of gravel (1/16 inch to 3/4 inch gauge) coated with 3½ per cent. of binder. The first layer is partially compacted before the second is applied and water is used freely in consolidation though to a lesser extent than in ordinary water-bound macadam. In most of the work done so far tar has been used entirely for pre-coating the metal and the gravel. For more recent work bitumen is being used for pre-coating the fine aggregate, tar being used as before for the metal. Ten miles have recently been laid to this specification and the results obtained so far are definitely superior to surface painted water-bound macadam. It was proposed to lay another thirty miles during the year 1933-34. Table II sets out particulars of cost of renewals carried out in the second Circle, Ambala, during the last financial year, where the bulk of new type of work has been carried out. These figures are based on metal costing Rs. 18 per 100 c. ft.; with metal at Rs. 25 a 100 c. ft. the cost would be more or less the same as that of cheap renewals *plus* one coat of tar. Where the metal costs more than Rs. 25 a 100 c. ft. water-bound premix is definitely cheaper.

9. *Thin Carpets.*—Though mere surface painting has been and is continuing to fill the bill, the time will come when a much stronger surface will be required. Earnest endeavours are therefore being made to ascertain the most economical method of dealing with the situation when it arises. Besides this, if this problem is solved, we shall not only have a specification for the treatment of existing roads but we can considerably cheapen new construction, for instance we could not only effectively deal with a brick on edge road which is so cheap to construct but we could also lay a protecting surface on a water-bound road made of soft metal or even of brick ballast. If these hopes are fulfilled, we shall have indeed made a definite step towards solving the road problem not only in the Punjab but throughout the whole of India.

10. With these objects in view experiments are being carried out with thin bituminous carpets on the lines set forth in specification, *vide* Appendix III. At the outset the specification adopted was somewhat different from that now given in Appendix III, the main point of difference being that the aggregate consisted roughly of a mixture of one part chips or river worn shingle of suitable grading and one part sand. The addition of sand was definitely beneficial not only on account of the greater stability derived but there was less tendency for the aggregate to crush. As far as the results are concerned this early work was very satisfactory, but owing to the presence of sand a power driven mixer was absolutely essential. Besides this, more bitumen is required but that is a minor point. The administration of India is such that there are literally scores of authorities in charge of roads who need to be convinced before a new specification can be introduced. Therefore to begin with it will be necessary to do work on a small scale in a large number of localities. If a

power driven mixer is a *sine qua non* very little headway can be made as it is most unlikely that an adequate number of such mixers will be available for what is after all only experimental work. The later specification (Appendix III) has been so framed that work can be carried out by means of a (home made) mixer operated by manual labour and only costing a few rupees.

11. It is found by experience that, provided the gauge of the finest particles in the aggregate is not less than say, about 1/12 of an inch, there is no difficulty in mixing by means of these home made contraptions. In the absence of sand a very great deal more care is required with the selection and grading of the aggregate. However this difficulty can be overcome far more easily then that of securing funds for a large number of power driven mixers. Moreover any deficiency in the matter of stability and tendency of the aggregate to crush under bullock cart traffic, can be made up by light applications of bitumen emulsion and covering the same with coarse sand. When premix work becomes more general, it may then be worth while purchasing a large number of these machanical mixers. It is therefore open to us to revert to the original specification with sand in the future.

The cost of laying a $1\frac{1}{4}$ inch bituminous carpet on a road with metalling 12′ wide is broadly analysed as follows :—

	Round figures. Rs.
1. Priming	250
2. 8,000 c. ft. aggregate at Rs. 18 per 100 c. ft.	1,450
3. 16 tons binder at Rs. 150 a ton	2,400
4. Labour	400
	4,500
5. Finishing coat of emulsion	1,500
Rs.	6,000

APPENDIX I.

TABLE I.

Cost of maintenance of metalled roads and surface painted milage on roads maintained by the Public Works Department, Punjab.

No.	Year.	Total length metalled.	Expenditure in lakhs.	Rate per mile.	Total length surface painted.	Remarks.
1	1924-25 ..	1503·58	24·66	1640	16	Width of metalling 12 feet.
2	1925-26 ..	1672·37	30·04	1796	24	
3	1926-27 ..	1863·30	33·12	1777	50	
4	1927-28 ..	2149·42	35·50	1651	73	
5	1928-29 ..	2439·114	39·83	1633	222	
6	1929-30 ..	2612·934	43·85	1678	369	
7	1930-31 ..	2667·084	45·82	1718	689	
8	1931-32 ..	2699	41·04	1521	1065	
9	1932-33 ..	2707	39·80	1470	1407	
10	1936-37 .. (forecast).	2710	29·70	1096	2710	When the entire milage has been surface painted.

TABLE II.

Particulars of renewals carried out in the Second Circle of Superintendence in 1932-33 (width of metalling 12 feet).

——	Stone plain W. B. M. Cheap renewals.	W. B. premix.	Kankar.	Totals and Averages.
Miles	155·72	10·50	97·0	263·22
Rate	2,404*	4,565	2,338	2,488
Cost	3,74,351	47,937	2,26,787	6,49,075

*Exclusive of tar painting which cost Rs. 1,600 for the first coat.

APPENDIX II.

Notes and specification for surface painting with Shalimar Road Tar on Water-Bound Macadam by S. G. Stubbs, O.B.E., I.S.E., Superintending Engineer, Second Circle, Ambala.

PRELIMINARY NOTES.

Tar painting may be advantageously carried out on either an old surface in good condition or a new surface soon after it has been consolidated and dried, but the tarring should never be carried out unless the road is thoroughly dry.

If there are any pot holes or ruts, treat surface in the manner described in paragraphs I and II below about a month before tarring is commenced.

IT IS NOT ADVISABLE to give out first coat application on contract unless it is certain that the contractor is trustworthy from all points of view. Initial coats of tar are the foundation for all future applications and it is imperative that such applications should be thoroughly sound.

I.—POT HOLES.

(*a*) *Over ¾ inch in depth.*—These should be made square or rectangular and excavated to a depth of 2 to 2½ inches, the bottom loosened and watered, filled with hard metal (1½ inch gauge) pre-coated with tar and rammed. The surface of the patches should then be covered about ⅝ inch thickness of pre-coated gravel (⅛ to ⅝ inch gauge) and again rammed. The quantity of tar needed is 3 per cent. by weight of the aggregate. Mixing can be carried out by means of the home-made appliance, Plate No. 1. If 5 per cent. by weight of fine kankar or limestone ($\frac{1}{16}$ inch to ¼ inch gauge) is added to the mixture (tar and metal) patches are considerably strengthened. In mixing, tar should be heated to 250°F., but the aggregate need not be heated. Patches should be consolidated with water and kept wet for a week as in the case of water-bound patches.

The approximate cost of the patching described will be Rs. 12 per hundred square feet or Re. 0-9-0 per cubic foot of patch work done (including cost of all material and labour).

(*b*) *Under ¾ inch in depth.*—Same as rut filling (*a*) and (*b*).

II.—RUT FILLING.

Ruts can be divided into classes :—

(*a*) Ruts up to ½ inch deep.

(*b*) Ruts from ½ to ¾ inch deep.

(*c*) Ruts above ¾ and up to 2 inches deep.

(*a*) *Ruts up to ½ inch deep.*—These should be painted with tar No. 1 or No. 2 at the rate of 5 sq. yards per gallon and covered with gravel ⅛ to ⅜ inch gauge at the rate of 3 to 3·5 c. ft. per hundred square feet, and well rolled or rammed and allowed to set for three weeks at least before tarring is done. If ruts are not completely filled in, or tarring has been done without rut filling, this operation can be repeated or carried out before the second application of tar. This process is more effective if done, say, in the months of September and March than in the middle of the hot weather because the gravel is easily displaced when the temperature is high.

Approximate cost of painting ruts will be Rs. 2-12-0 per hundred square feet or Rs. 200 for filling one rut 1½ feet wide per mile.

(*b*) *Ruts from ½ to ¾ inch.*—The surface of the rut should be painted with tar No. 1 or No. 2 at the rate of 7 to 8 sq. yards per gallon and then 2½ per cent. premix of ⅛ to ⅜ inch gauge gravel filled in the rut and well rolled and allowed to set at least for 10 days before tarring is done. This should never be done in the middle of the hot weather.

Approximate cost Rs. 4 per hundred square feet or Rs. 300 for filling one rut 1½ feet wide per mile.

(*c*) *Ruts above ¾-inch and up to 2 inches.*—These should be scarified to a depth of 1½ to 2½ inches and new metal added and consolidated as ordinary water-bound macadam. Great care should be taken that the metal of the unscarified surface adjoining the ruts is adequately protected to prevent crushing.

Approximate cost for filling two ruts 1½ feet wide will be Rs. 500 per mile. As the cost of renewals are now so cheap, rut filling should only be done where it is certain that by doing so the road surface will be brought to proper camber, otherwise the whole surface should be renewed.

Methods II (*a*) and II (*b*) should not be adopted where the joints on the surface of ruts cannot be adequately raked out. If the tar does not penetrate sufficiently there is danger of peeling off as the ruts bear the full brunt of the bullock cart traffic.

III. For at least two weeks before tarring is done the road surface should not be blinded with earth.

IV. Tarring as far as possible should be done in warm weather when the sun temperature is 100°F. or over, so as to ensure more penetration and uniform distribution of tar over the surface of the road.

V. If possible the whole width of the road should be closed to traffic, and the berm on the leeward side only used for traffic and this should be sprinkled with water to reduce dust to a minimum.

MATERIALS.

Stone chips or gravel.—The proper function of the binder should be to securely fix the chips in position and that of the aggregate to take up the wear of traffic, therefore the quantity of aggregate should be as large as possible in relation to the quantity of binder. Experience shows that for initial applications the relation is 250 c. ft. aggregate to 1 ton of tar and for second and subsequent coats 300 c. ft. to 1 ton of tar. This works out at about 3 c. ft. of aggregate per 100 sq. ft. of road surface for initial applications and 1·8 c. ft per 100 sq. ft. for second and subsequent applications.

As the aggregate is to take the wear it should be as hard as possible and where available it should consist of hard river bed gravel or very hard crushed stone chips.

Experience shows that the very fine particles should be reduced to a minimum, and no stuff less than 1/8 inch gauge should be used, otherwise a larger quantity of binder per unit of volume of aggregate will be needed.

The following grading of chips or gravel has produced very satisfactory results :—

For initial applications :—

⅛ to ¼ inch gauge	40 per cent.
¼ to ¾ inch gauge	60 per cent.

For subsequent applications :—

⅛ to ¼ inch gauge	40 per cent.
¼ to ⅝ inch gauge	60 per cent.

SURFACE PAINTING WITH ROAD TAR (FIRST COAT).

Initial application consists of the following four operations :—

(1) Cleaning the road surface.

(2) Heating and pouring tar.

(3) Spreading stone chips or gravel.

(4) Rolling stone chips or gravel.

1. *Cleaning the road surface.*

This consists of five operations :—

(*a*) Sweeping the road surface with ordinary brooms or soft brushes with long handles to remove the surface dust.

(b) Removing caked mud from the edges of the road by means of miniature picks. This mud cannot be removed by ordinary wire brushes.

(c) Cleaning the road surface with wire brushes so as to loosen the mud and fine blindage from the interstices of the road.

(d) Cleaning the road surface with soft brushes so as to remove dust and blindage produced in operation (c).

(e) Final dusting of the road surface with gunny bags or country whisks to remove fine dust.

2. HEATING AND POURING TAR.

(a) *Heating tar.*—The tar should be heated in tar boilers as far as possible and if the tar boilers are not available, heating can be done in boilers locally made from tar drums.

In case of B. S. S. Tar No. 1, the temperature should be maintained between 220°F. and 240°F. and in case of B. S. S. Tar No. 2 between 240°F. and 250°F.

Great care should be taken that no water from the tar drums or any other source enters the tar boiler, otherwise the tar will overflow with disastrous results to the operators.

A full tar drum should always remain suspended over the tar boiler, so that the contents will never be reduced to say less than ¼ of its volume, otherwise the accumulated heat stored up in the fire bricks will cause a very rapid rise in temperature.

(b) *Pouring tar on road surface.*—This is done in two ways:—

(i) *Spraying.*—After the surface of the road is thoroughly cleaned and well dusted as described in operation No. 1, the edges of the road should be well defined by means of ¼ inch thick strings 50 to 100 feet long each. In spraying tar with the sprayer great care should be taken that the tar is sprayed uniformly along the length of the road and never across the road. If sprayed across the road, unsightly overlapping will occur and even when spraying longitudinally overlapping should be reduced to a minimum by brushing.

The quantity of tar used during spraying can be controlled by means of flat iron gauges, but an expert sprayer operator should be able to gauge the quantity sprayed by eye. The height at which the sprayer is held is the controlling factor. One gallon of tar sprayed should cover 5 square yards of road surface.

(ii) *Hand pouring.*—After cleaning (operation 1) the edges of the road are demarcated by means of ¼ inch thick strings 50 to 100 feet long pulled taut and secured, then marks are made at 7½ feet intervals on the berms to represent the length of the road that will be covered with two gallons of tar. Pouring is now done by means of pouring pots of one gallon capacity. Thus the contents of two pots will cover a length of road represented by one marking on the berms and this will amount to 5 square yards per gallon of tar.

Pouring and brushing should be done longitudinally and overlapping reduced to a minimum.

The operation of pouring is carried out by two men equipped with soft brushes with long handles and one man with a pouring pot filled with one gallon of tar and these men pour and brush the tar on the road simultaneously.

One stroke of the pouring pot covers one foot width of a road 7½ feet long (the most convenient length of road that can be dealt with) and 6 strokes are sufficient to completely empty the pot, thus a width of 6 feet, 7½ feet long can be covered with one pouring can.

The foregoing refers to an initial application for a road 12 feet wide. In case of subsequent applications one pouring pot will cover the whole width of 12 feet, 7½ ft. long.

Given a moderately smooth surface and a sun temperature of not less than 100°F., it is possible to spread tar in this way as rapidly and as evenly as with a sprayer. Experience seems to indicate that if work is done in the hot weather better results are obtained by hand pouring.

The position of the tar boiler should be so adjusted that minimum time will be taken in carriage of tar from the boiler to the road.

The labour employed on heating and pouring tar should be provided with goggles, long boots and a pair of putties for protection.

3. Spreading stone chips or gravel.

Before spreading, gravel should always be screened through a 1/8 inch mesh screen, so as to remove fine dust. Crushed stone chips or river bed shingle of hard quality and 1/8 to ⅜ inch gauge should be spread over the surface evenly immediately after pouring the tar. Uniform spreading can be ensured by regulating the number of baskets needed per definite length of road. 12 baskets of ¼ c. ft. capacity are needed for 9 feet length of road 12 ft. wide.

The greatest care should be taken that the chips are evenly distributed (by means of drag brooms or in any other way) over the surface otherwise the riding qualities of the road surface are likely to be impaired.

4. Rolling stone chips or gravel.

As soon as possible after the chips or gravel is spread the surface should be rolled with a 10 ton or 8 ton roller and rolling continued until the gravel has stuck to the road surface Rolling should not be overdone, generally 6 to 8 trips of the roller are found sufficient.

General.—Traffic can be permitted on a freshly tarred surface after sundown on the day work was done, but if possible traffic should not be allowed to use such a surface during the hottest part of the day until the tar is 24 hours old, otherwise the chips or gravel is very liable to be displaced. Watering a road after sundown on the day tarring was carried out is distinctly beneficial where sun temperatures are very high because it takes many hours for a road to cool down.

Surface painting with road tar (second coat).

In addition to the necessary preliminary work already described, this consists of the following four operations :—

(1) Cleaning the road surface.

(2) Heating and pouring tar.

(3) Spreading stone chips or gravel.

(4) Rolling stone chips or gravel.

(1) Cleaning the road surface.

This can be sub-divided as follows :—

(*a*) Scraping off the manure or other foreign matter sticking on to the road surface by means of any suitable implement.

(*b*) Cleaning the surface with wire brushes, loosening any stuff left out by operation (*a*) specially at the edges.

(*c*) Cleaning the surface with soft brushes so as to remove dust and foreign matter produced in operations (*a*) and (*b*).

(*d*) Final dusting of the road with gunny bags or country whisks to remove fine dust.

(2) Heating and pouring tar.

(*a*) *Heating tar.*—Same as paragraph 2(*a*) of specifications for first coat of tarring.

(*b*) *Pouring tar.*—(*i*) *Spraying.*—Same as paragraph 2(*b*)(*i*) of specifications for tarring first coat except tar is sprayed at the rate of 10 square yards per gallon of tar.

(*ii*) *Hand pouring.*—Same as for paragraph (2)(*b*) (*ii*) of specifications for tarring first coat with the exception that the space between the marks on the berms will be covered in one pouring of a 1 gallon capacity pouring pot. This works out at 10 square yards per gallon of tar.

(3) Spreading stone chips or gravel.

Same as for paragraph 3 of specifications for first coat of tarring with the exception that the gauge of the gravel should be 1/8 to 3/8 inch and that 7 baskets containing 1·8 c. ft. gravel should cover 8 to 9 feet length of road 12 feet wide.

(4) Rolling chips or gravel.

Same as for paragraph 4 of specifications for tarring first coat.

General.—Same as for first coat work.

Analysis of cost of tarring and gritting per mile of 12 ft. road, or 7,040 square yards, excluding tools and plant charges.

FIRST APPLICATION.

Materials.

	Rs.
B. S. S. No. 2 tar 8 tons at Rs. 125	1,000
Grit 2,000 c. ft. at Rs. 20 per 100 c. ft.	400
Total materials	1,400

Labour and fuel for treating and applying.

(*i*) Cleaning road surface: The accounts show an expenditure of Rs. 7,476 for 107·80 miles or Rs. 69 per mile.

(*ii*) Heating and spraying or pouring: The accounts show an expenditure of Rs. 4,111 for 854·35 tons of tar or Rs. 4-13-0 per ton.

(*iii*) Spraying grit or gravel: The accounts show an expenditure of Rs. 1,329 for 176,674 c. ft. of grit or As. 12 per 100 c. ft.

(*iv*) Rolling: The accounts show an expenditure of Rs. 4,003 for 107·80 miles or Rs. 37 per mile.

Abstract for 1 mile.

	Rs.	a.	p.
(*i*) Cleaning surface	69	0	0
(*ii*) Heating and spraying or pouring 8 tons Rs. 4-13-0 per ton.	36	8	0
(*iii*) Spreading grit or gravel 2,000 c. ft. at annas 12 per 100 c. ft.	15	0	0
(*iv*) Rolling	37	0	0
Total fuel and labour	157	8	0
Say	160	0	0
Add materials as above	1,400	0	0
Total cost per mile	1,560	0	0

SECOND APPLICATION.

The analysis has been made from actual costs as before, and the abstract is:—

	Rs.	a.	p.
B. S. S. No. 2 tar 4 tons at Rs. 125	500	0	0
Grit or gravel 1,200 c. ft. at Rs. 20 per 100 c. ft.	240	0	0
Heating, spraying and rolling	110	0	0
Total for one mile	850	0	0

APPENDIX III.

Specification for $1\frac{1}{4}$ inch premix carpet using bitumen as a binder.

Material and Plant.

Aggregate.—This should consist of either river worn gravel or broken stone chips. As failure in these carpets is more due to crushing than to any other cause, therefore the material in either case should be as hard as possible. Though broken stone chips are preferable for greater stability it is not often possible to obtain really hard stone chips at a reasonable price on account of the high cost of breaking.

The following is a suitable grading for either river worn shingle or broken stone chips :—

$\frac{1}{4}$ inch to $\frac{3}{4}$ inch	50 per cent.
1/8 inch to $\frac{1}{4}$ inch	25 per cent.
1/12 inch to 1/8 inch	25 per cent.

Binder.—This should consist of 2 parts of (20—30) penetration Mexphalte and 1 part Shelmac. It is understood from the suppliers that the Shelmac consists of 88 per cent (20—30) penetration Mexphalte and 12 per cent. solvent, therefore the mixture consists of 94 per cent. (20—30) Mexphalte and 6 per cent solvent. In the process of mixing, the Mexphalte is heated to 350°F and allowed to cool to 300°F and the Shelmac is added cold, when the two have been thoroughly mixed the binder is ready for use.

Mixer.—(See plan at Plate No. 1.) This is a "home made" contraption and is operated by manual labour (4 men). It consists of 2 parts, that can be easily separated, the revolving portion and the underframe. The former is made of 2 bitumen drums and a steel spindle, while the latter is made up of any rough wood though it is essential that the top part of the vertical should consist of some hard wood like "shesham" or "kikar" as no metal is used for the journals of the bearings. It has been found by experience that this arrangement is very satisfactory as neither the spindle nor the joining wear away appreciably if sufficient grease is used. In order to minimise handling and transporting coated aggregate the mixers are operated actually on the road surface. After pre-coating, each batch of aggregate is deposited straight on the road surface and the mixer is lifted up and carried forward, this is facilitated by the fact that the mixer is made in 2 parts. If skilfully operated one mixer is quite capable of coating about 200 c. ft. aggregate in an eight hour working day, therefore a battery of 5 would be quite sufficient to feed a steam roller working at its fullest capacity.

Proportion of binder.—The relation between quantity of binder and aggregate depends on several factors the chief of which are grading and character of the latter. Under average conditions with grading as specified 2 tons of binder is sufficient to coat 1,000 c. ft. of aggregate.

Priming.—These carpets can either be laid on a previously painted surface or straight, on water-bound macadam. In all cases it is much the safest plan to prime before laying, as satisfactory adhesion to the underlying surface adds considerably to the strength of the carpet. Priming especially if a low viscosity bitumen is used should not be overdone as this may possibly cause "pushing". Satisfactory results have been obtained with the following methods of priming :—

(*a*) *A surface previously painted with tar.*—No. 1 or 2 tar, preferably the former applied at the rate of 1/15 to 1/20 gallon per sq. yard. A satisfactory method of priming with such a thin coat is by liberally pre-coating a small quantity of gravel with tar and brushing it along the road surface, used in this way the gravel acts as a vehicle for distributing the tar.

(*b*) *A surface previously painted with bitumen.*—Same as (*a*) except that a higher percentage of solvent is used than contained in Shelmac to facilitate distribution.

(*c*) *A water-bound surface.*—Same as (*a*) or (*b*) but the rate of application should be increased to about 1/8 of a gallon per sq. yard. As an alternative bitumen emulsion might be applied at the rate of 1/6 to 1/8 of a gallon per sq. yard, but this will be more expensive.

Constructional operations in order of sequence.

(*a*) *Preparation of surface.*—The surface to be treated should be thoroughly cleaned in the usual manner prescribed for tar surface painting. After cleaning the surface, wooden strips 2 inches by $1\frac{1}{4}$ inches are securely fixed along the edge of the metal by the edge of the metal by means of steel spikes and remain in position until the carpet has been finally rolled and has set. These wooden strips not only support the carpet during laying but act as a gauge for the thickness of the carpet.

(*b*) *Priming.*—The surface is suitably primed adopting one or other of the methods described under the head priming.

(*c*) *Mixing.*—Four to five " home made " mixers are placed in such positions on the primed surface that the work of spreading of the coated aggregate is reduced to a minimum. Before being placed in the mixers the aggregate is screened into 2 gradings, *viz.*, material about 1/8 inch gauge and material below 1/8 inch gauge. The former is first put into the mixer and then 2/3 of the requisite quantity of binder is added and the mixer revolved 20 times, the fine stuff is now added and the mixer again revolved and finally the remainder of the binder (1/3) is added and mixing completed. Unless the seemingly complicated sequence of operations is carried out the fine stuff will "ball up " and uniform pre- coating will not be possible. With a sun temperature of not less than 100°F. there is no need to heat the aggregate, but with a lower temperature it may be necessary to heat either the whole of the aggregate or the portion of it with particles less than 1/8 inch gauge. Mixing may also be facilitated by lightly spraying the aggregate with kerosene by means of a " FLIT" gun.

(*d*) *Spreading.*—After depositing the precoated aggregate on the primed surface it is evenly spread by means of rakes and these should be the only tools used for spreading. Compaction by foot, hand or rammers of any kind should be avoided at any cost.

(*e*) Rolling should be done by a 6 or 8 ton roller, though a 10 ton roller could be used if the aggregate is not too soft. Tandem rollers are the most suitable for this class of work, but their use is not essential.

(*f*) Bitumen emulsion should be sprayed at the rate of 1/8 gallon per square yard and covered with course sand. Though generally speaking this final application is not always essential it is recommended for roads carrying heavy bullock cart traffic, as the tendency of the aggregate to crush is considerably reduced.

General.—Motor traffic should be kept off the road for 4 days and bullock carts for one week to ten days after completion. If possible traffic should be diverted right away from the road during construction, if traffic travels along the berms dust is blown on the surface before the solvent in the mix has evaporated and a good deal of it (dust) is incorporated in the mix thus making it too dry. Special provision should be made for diversions and the best way of dealing with the traffic is by laying a temporary wire roadway especially in cases where traffic has to use the berms.

[Paper No. 5 (b).]

Notes on the Uses of Tar, Bitumens and Emulsions, in the Punjab, Being a Paper Contributed for the Last (1934) International Roads Congress.

BY

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NOTE.—The paper has been slightly curtailed by the elimination of matter not necessary for a body of Engineers in India.

TAR.

1. *Tar. Present attitude towards use of tar in the Punjab and Northern India.*—India is probably one of the most conservative countries in the world, and it is certainly an achievement that now a days, in the Punjab at any rate, the application of some form of waterproof surfacing is regarded as being essential for main roads. This conviction has been reached during the past few years, before that the Public and the administration, provincial and local were reconciled to the annual reconstruction of large sections of water bound road, with all its inconvenience and annoyance to the public. Since the advent of the motor few, water-bound road crusts could survive more than a couple of years, and in the more heavily trafficked sections 6 months was the not unusual limit of endurance. Until quite recently tar was considered an unknown quantity, a luxury, an unjustifiable expenditure, and a concession to the "speed fiend"; in a very similar manner to the outcry which was raised in England, when surfacing of rural roads on a large scale was inaugurated before the war.

2. *Failure in the past.*—It is true that early experiments, involving the use of improperly dehydrated tar, did not create confidence. Such tars were unsuitable for road work and in the heat of Indian summer bled to an uncomfortable extent. Too much tar was used on occasions, a cause of high cost, and too little was known regarding the use of fillers or grit.

3. *Saving as the result of extensive surfacing over 3 years.*—Until about 1930; the hands of road Engineers were tied, and they were robbed of initiative because the application of any surface treatment required the sanction of the Legislature as an " original work ". In June 1930 this embargo was removed and it is now the rule that *all new water-bound macadam must be waterproofed* at the earliest opportunity. The result has been a saving of nearly 28 per cent. in the maintenance bill for arterial roads in the Punjab, a figure which will increase as tarring progresses, as it has not yet been financially and physically possible to surface more than approximately half of the 2,700 miles of the arterial metalled roads in the Province.

4. *Improvement effected.*—The results of this wide spread use of tar has undeniably raised the standard and lengthened the life of roads in this Province. Hitherto water bound roads, however well consolidated and founded, were quite inadequate for the fast and heavy motor traffic of the present day, and in

some of the more heavily trafficked areas were impassable after six months use Moreover, in dry periods the clouds of dust raised by quick moving vehicles were not only a danger to health, and a public nuisance, but rendered visibility difficult and increased road accidents. Although it cannot be claimed that the standard of Punjab roads can be compared with the modern roads of European Countries, the surfacing or painting of water bound surfaces has established a highway which allows touring cars to travel at high speed, in comfort and in safety, and from the motorist and the road carrier's point of view, a permanently good surface has meant immense savings in tyre and engine depreciation, and oil and petrol consumption.

5. *Use by animal drawn vehicles.*—In the Punjab the horse drawn "tonga" and the springless bullock cart, of some 15 cwt., are still the normal vehicles of the people. Opposition to the surfacing of roads might have come from those quarters, but although it is possible for such vehicles to use the sides or "berms" of the roads, draught animals appear to acquire quickly the habit of using the tarred road with ease and confidence. This is true even of long gradients on the Rawalpindi-Murree-Kashmir Road, where grades are as much as 1 in 18 for 12 miles stretches.

6. *Advantages.*—In tar surfaced or bound roads a product is achieved which is cheap, efficient indigenous (an important point in a country of high tariffs such as India) easily laid by unskilled labour, dust proof and lasting. In certain localities the only stone available is of a soft and friable nature, such as sandstone, or of a very hard and unyielding nature, with poor cementitious properties, such as quartzito. Prior to the advent of tar surfacing such metal was of little value as road metal either by reason of its rapid attrition, or its poor binding quality. Excellent and economical results have been accomplished by tar surfacing such material, and there are even greater possibilities if and when the use of tar or bitumen, as binders is generally accepted and established.

7. *Facility of laying.*—There also appears to be a greater permissible "margin of error" with tar than with other commodities, and very few failures occur. This is a great advantage in a country where expert supervision is difficult to obtain, and labour extremely unskilled.

Further, tar appears to lend itself to rather primitive methods. Tarsprayers, special boilers, gritting machines, motor tandem rollers, etc., the usual means by which surfacing is normally executed in European countries, are regarded with suspicion and dislike by governmental financial control. There is perhaps some justification for this attitude, since machinery of any sort is often abused and misused by untutored Indian contractors, and unless expert supervision is available, depreciation is unusually rapid. Moreover, few machines of local manufacture are available, and there is a natural tendency to avoid purchase of articles of foreign manufacture as much as possible. Conditions of financial stringency tend to stiffen this attitude, and improvision and resource to suit local condition is called for.

8. *Manufacture.*—Northern India is dependent on Tar supplies from the Bengal Coal Field. This is distilled by certain refiners to British Standard Specifications and railed from the coalfields of B engal a distance of some 1,300

miles to Rawalpindi. The cost of the freight over this distance is Rs. 35 per ton whilst the tar at source cost Rs. 97. Tar No. 2 is chiefly used in this locality—although No. 1 and High Viscosity Tar have been used with success elsewhere.

9. *Local resources.*—Although a shaly coal of inferior quality is mined in the Salt Range of the Punjab, it is unlikely that tar distillation will ever be a commercial proposition ; for no demand exists for coke, in the making of which crude tar is a bye-product. It seems therefore that the Bengal coalfields must be relied on as the only source of supply ; although it is within the bounds of possibility that the carriage of road tar in bulk will be feasible, thereby reducing freight and the cost to the consumer.

10. *Methods employed in Tar surfacing.*—Tar can be successfully heated in batteries of barrels, the usual containers, on special stands, and in the absence of sprayers, can be laid with fair success by pouring from ordinary water cans, fitted with rose nozzles, the spread being obtained by squeegees of rubber flaps and brushes. Grit or chippings are spread by casting in a circular motion from flat baskets, and the Punjabi coolie can be trained to lay such material with speed and precision.

11. *Cost of Tar.*—Tar is available F. O. R. Rawalpindi at the rate of Rs. 132 per ton carried in non-returnable steel drums each of 4½ cwt. capacity. It is railed in wagons of about 13 tons capacity. Local carriage is done by country bullock carts at a cost of 11 annas per ton mile, and the tar is dumped at site in units of 3 barrels spaced at intervals along the road.

12. *Chippings or Grit.*—The grit or chippings used for blinding (known by the vernacular name of "bajri") is obtained from river beds in the locality and is water worn limestone pebble of considerable resistance to crushing. The approved range of size is from 1/8 inch to 1/4 inch (to pass 3/8 inch mesh). The material is usually screened at site and stacked on spare road side land. The cost of such material varies according to the distance of final disposal and the method of carriage employed. For instance pebble from the River Haro costs Rs. 7 per 100 cft. at site near the river bed but Rs. 30 per 100 cft. stacked at mile 24 on the Rawalpindi-Murree-Kashmir Road. (It should be stated that the Haro pebble is particularly suitable for tarring work). In view of difficulty of obtaining river bed stone at all times of the year and the unlikelihood of strict compliance to specification by local contractors, supplies have occasionally been obtained of machine crushed limestone. Such material is less durable than water worn pebble but the certainty of supply and standard is an asset in its favour. The cost is slightly more than limestone pebble.

13. *Cost of completed Tar Surfacing.*—The cost of completed work varies according to site, from Rs. 2-4-9 to Rs. 2-12-0 per hundred square feet for the first coat and from Rs. 1-6-0 to Rs. 1-11-0 for the second coat. An analysis of costs is attached for information (Appendix A). These figures relate to 1932 and recently it has been possible to tar with second and third coats at Rs. 1-3-0 per hundred square feet.

14. *Specificaton for laying.*—A specification as used in the Punjab is appended (Appendix B). With regard to the application of the specification in practice, it should be noted that the few failures that have occurred appeared to have been due to imperfectly cleaned roads. In a dry dusty country such as the North of India, the thorough cleaning of water bound macadom roads is a matter of considerable difficulty especially with traffic of all sorts moving on side diversions. An occasional cause of failure is the over heating of tar (250°F. is the ideal), but this seldom occurs. if suitable sprayers are available (such as the "Phoenix" rapid Hand Tar Sprayers fitted with plunger pump and scythe spraying nozzle), a smooth controlled spread is easily and quickly obtained; when hand methods must be used unevenness in laying must be carefully guarded against. Special treatment of the edges of the metalling is also necessary. Since Punjab roads are usually devoid of haunching or kerbing, the margin at times becomes aerated and broken by traffic, particularly when wear of berms occurs.

15. *Steam Rollers.*--Owing to the limited funds available for the supply of road tools and plant, use has to be made of such steam rollers as are available. The majority of these are of 10 to 12 tons, and are too heavy for rolling chippings into tar without undue crushing. A more extended use of local quarry products and "bajri" from hill streams would probably result from the use of light motor rollers 3 to 5 tons. At present the high cost of railing the hardest and most durable water worn bajri for considerable distances is a big item in the cost of tarring.

16. *General.*—It can be safely said that the use of tar surfacing has saved the situation as far as road economies are concerned in the Punjab. With an under-developed but projected extensive system of arterial roads, and an ever-increasing demand for more and better highways the factors are present for a stimulus to road making activity.

Increase of Motor Vehicles.—An indication of the increased demand for roads is given by the figures of motor registrations in the Punjab for the past years. These have grown from 14,000 in 1928 to 25,000 in 1932. They do not include military Motor Vehicles which have also increased in recent years.

17. *Road Classification Scheme of 1927.*—A reclassification scheme drawn up in 1927 indicated the lines on which development would proceed; a further fillip to progress was achieved with the special Road Tax on petrol, and the formation of the Central Road Development Fund by the Government of India, from which grants for new constructions were made to Provinces. Nevertheless with an ever-increasing annual bill for maintenance, it was natural that Government should look askance at further liabilities in this direction, and a tendency is evident to apply funds intended for the development of the road system, towards lightening the heavy and increasing burden of ordinary maintenance. But, as has been stated, the great saving achieved by road surfacing during the past three years has paved the way to more confidence in promoting further development of the road system.

18. *Question of life of tar road.*—It is of course a moot point how far this decrease in recurring expenditure will be progressive. Much

depends on the extent to which it is necessary to renew the water bound metalling in the years to come. An average view is that this will be necessary within 12 years; although it is optimistically held in some quarters that a carefully maintained and renewed tar road will last for ever. In support of these statements it should be recorded that the Mall, Lahore, the main thoroughfare of the Capital of the Province, was last remetalled and originally tarred in 1916, and for the 17 years has withstood heavy traffic with very little ill effect. But it would appear that the "limit of saturation" is reached at about 600 tons to the yard width, and there are certainly stretches of road in the vicinity of large Punjab towns, where such condition has been attained.

19. *Tar used as binder or matrix.*—Not much progress has been made in recent years in the application of Tar, Bitumens, etc., as incorporated binders. The reasons for this are probably as follows:—

(*i*) Cost.

(*ii*) This is "Original work" and therefore requires special sanction as such.

Recently, however, premixed tar carpets have been tried with a view to economies in metalling of the sub-grade, the latter being reduced from 4½ inches to 3 inches. The method adopted is to use 1 inch of chippings premixed with No. 2 Tar and allowed to cool off for ten days. Before laying the existing road surface has to be treated or painted with tar No. 1. The cost of the one inch thick premixed carpet is in the neighbourhood of Rs. 7 per hundred square feet. Such work as has been done is experimental and its life and capacity remains to be seen and at present it would appear that, when metal is plentiful and cheap, tar surfacing at Rs. 4 per hundred square feet (two coats) remains the more economical method for roads carrying traffic upto 250 tons per yard width.

20. *Tar and pitch grout.*—A mixture of tar and pitch has been used with some success where the cost of metal was abnormally high due to distance from source of supply, *e.g.*, in the plains at distances of 300 and 400 miles from the nearest quarries. Here the aggregate has often been usually burnt and broken to 2″ gauge at site, and used 3¼″ thick consolidated; the binder or matrix being tar mixed with pitch in the proportion 1 tar : 1 pitch for grout, and 1 tar : ½ pitch for seal coat. Imported hard stone grit is of course used for the sealing surface (on Lahore-Harike Road 1929). The cost of this type of work was Rs. 27 per hundred square feet or excluding the cost of brick metalling Rs. 22. The work was admittedly experimental but good results have been obtained over a number of years on light trafficked roads. The admixture of pitch with tar is, however, of doubtful efficacy in the Punjab, and tar alone as a matrix should give equally good, if not better, results with broken brick aggregate using about twice the amount of tar required for stone.

Bitumens.

21. *Initial paint coats not a success.*—Bitumen is an imported material. It has been used in the past as a binder with varying success for premix and

grouting and even "pave work", *e.g.*, whole burnt bricks steeped in bitumen. Formerly initial seal coats or surfacing work of an experimental nature were tried on various roads in the Punjab, but in the majority of cases were a failure. It would appear that the difficulty of the thorough removal of dust from the water bound surfaces was responsible for the lack of success. Bitumen in liquid state in contact with dust appears to lose its property of spreading and the carpet or coating may be as easily removable from the sub-grade as a mat from a floor. However, recently the use of "Spramex" has been extended for second and third coats over initial coats of tar and with much success. Over tar a smooth, even, surface is obtainable, which appears to be tougher and more lasting than tar. Its application is more difficult than that of tar, and a properly equipped sprayer is an essential. Successful surfacing with this material is obtained so long as the coat is laid thin. Failure has occurred through an excess of the bitumen resulting in ridging and unevenness. At a cost of Rs. 146 ton, "Spramex" compares favourably in price with tar (Rs. 132) and at Rs. 1-10-0 per hundred square feet, it is probable that its use will be extended for second and subsequent coats. A great disadvantage is its slipperiness in winter.

Emulsions.

22. From the foregoing it would appear that emulsions which require no heating, and can be easily poured from their containers, should be extensively used for surfacing. There are a variety of emulsified tars and bitumen on the market, but at present their high cost in the Punjab have not made their general use possible. Emulsifying plants at present exist only at seaports, or large cities, such as Peshawar and Lahore at distances varying from 200 to 800 miles, and therefore water carried in bulk represents much of the cost of transport.

Examples of emulsions in use are:—

(*a*) "*Colas*" an emulsion of bitumen marketed by the Burmah-Shell Company. This material cost last year Rs. 157 at Peshawar and with freight to Rawalpindi, etc., cost Rs. 167-4-0 at site of work. The cost per hundred square feet was Rs. 2-12-0 for a second coat over tar. The price of this has been recently reduced to Rs. 140 ex-factory.

(*b*) "*Bitumuls*" an emulsion of American origin marketed by Shaw Wallace and Company, Calcutta. Cost at Rawalpindi Rs. 157-4-0 per ton at site, and cost of second coat over tar Rs. 2-10-0 per hundred square feet.

(*c*) "*Mexaco*" a road oil, said to contain 65 per cent. of bitumen, made by Road Oils (India), Calcutta, cost at Rawalpindi Rs. 197-8-0. Cost of a second coat Rs. 2-5-0 per hundred square feet. This is a thin bodied material of great covering capacity.

It will be seen however that these figures compare unfavourably with tar at Rs. 1-7-0 hundred square feet for second coats. With labour costs being such a minor item of expenditure, there is no set-off to the additional quantities used. For whereas 1/10th of a cwt. of tar will cover one hundred square feet,

it requires 1/5th to 1/4th of a cwt. of emulsion to do the same, the additional weight being largely water. Bitumen emulsions have, however, been used with success over initial costs of tar. At present their high cost in comparison with the latter does not seem to be justified. For first coats over water-bound surfaces, they have not been successful so far.

23. *Slipperiness.*—With a range of shade temperature of from 30°F. to 115°F. road surfaces in Northern India are subject to a wide variety of weather condition and stress, but as the rainfall is more or less confined to a few months in the year, there is far less occasion for roads to get muddy or greasy than in Western countries. Tar definitely gives a surface of a rougher texture than bitumen, and is less liable to cause skids when wet.

24. *Tar on steep grades.*—In the last two years the Rawalpindi-Murree-Kashmir-Road has been surfaced as far as Kohala, the Kashmir boundary. Owing to the extended use of this road by bullock and mule carts, and to the hilly nature of the road with innumerable curves and "hairpin bends", the water proofing of the road, though urgent in view of very heavy lorry and other motor traffic, was for some time avoided because of the fear of accidents from excessive slipperiness. This road rises from Rawalpindi, at 1,720 feet above sea; level to Murree (at 6,697 feet), with one section of 13 miles at a grade of 1 in 18 and then falls to the river Jhelum at Kohala, the Kashmir boundary, at an average grade of 1 in 27; the total distance being 64 miles. The road has been tar surfaced during the past two years, and it would seem that the miscellaneous traffic, normal to the Indian road, still can use it with ease, comfort and safety, and that with good traffic control, accidents are extremely rare at all times of the year, even in winter when the hills are frost bound, and snow clearance is necessary for a period of three months. Bitumen surfacing, is, however, avoided on the steep grades (steeper than 1 : 30).

25. *Conclusion.*—The use of tar in the North of India for road surfacing has proved its value and has come to stay. In future roads of more permanent and solid construction will probably be necessary as the intensity of traffic increases; moreover since Portland Cement is manufactured in the Province, the construction of concrete roads appears to be the solution. But initial costs are a very great consideration.

26. Road loans are under consideration and it may be that as a result development will proceed on more modern lines and recurring maintenance charges be reduced to much smaller proportions. But this can only be an achievement of the future. Meanwhile the situation is being saved by the use of the tar. Annual expenditure is being reduced, the road user, particularly the motorist, is assured of a permanent and reliable road, the road fabric is protected and preserved, and journeys are quicker and safer.

APPENDIX A.

Statement showing comparison of analysis of figures for the first coat tarring in all Sub-Divisions of Rawalpindi Provincial Division.

Serial No.	Sub-Division.	Arterial road number.	Cost of tarring when new bajri is used.					Cost of tarring when scarified bajri is used.					Remarks.
			Average cost of tar required for 100 s. ft. of Road Surface.	Carriage to site.	Cost of new bajri for 100 s. ft. of tarring.	Brushing Cleaning Road, heating tar, spreading tar and Rolling.	Total cost Column 4+5+6+7.	Average cost of tar required for 100 s. ft. of Road Surface.	Carriage to site.	Cost of screened bajri from scarified metal.	Brushing cleaning road, heating spreading tar and rolling.	Total cost column 9+10+11+12.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
			Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	
1	Jhelum Sub-Division.	G. T. Road Arterial No. 1	1 11 0	0 0 4	0 9 5	0 5 3	2 10 0	1 11 0	0 0 4	0 7 2	0 5 3	2 7 9	
2	Rawalpindi Sub-Division.	Do. ..	1 11 0	0 1 0	0 4 6	0 8 0	2 8 6	1 11 0	0 1 0	0 0 0	0 8 0	2 4 0	
3	Do. ..	Do. ..	1 11 0	0 1 0	0 7 3	0 8 0	2 11 3	..	..	..	..	..	Bajri from Wah is used.
4	Rawalpindi-Murree Sub-Division.	Rawalpindi-Murree-Kashmir Road Arterial No. 11.	1 11 0	0 1 0	0 4 6	0 8 0	2 9 3	1 11 0	0 1 0	0 0 0	0 8 0	2 5 0	
5	Murree Sub-Division.	Do. ..	1 10 0	0 5 6	0 8 6	0 8 0	3 0 0	1 8 0	0 3 0	0 0 0	0 8 0	2 12 0	Water worn shingle mixed with scarified Bajri.
6	Do. ..	Do. ..	1 10 0	0 4 0	0 8 0	0 8 0	2 14 0	1 8 6	0 5 0	0 1 6	0 8 0	2 7 0	Old and new Bajri.
7	Campbellpur Sub-Division.	....	1 12 0	0 2 0	0 6 0	0 8 0	2 11 0	1 12 0	0 2 0	0 1 0	0 8 0	2 7 0	

APPENDIX B.

Tar Surfacing (Tar applied Hot). Specifications and conditions (revised 1932-33).

1. *Definition and scope.*—" Tar surfacing " is distinct from " Tar painting " and consists of a wearing cushion or coat applied to the surface of water bound macadam, with the object of providing better skin binding to the metal, and a cushion to reduce wear, and thus extend the life of the macadam and indirectly to afford a smooth and dustless travelling surface. Strictly speaking it consists of grit (bajri) held together with tar to form a conglomerate or tar macadam, laid to fill all irregularities in the water bound macadam surface and bringing the same up to a smooth and even water-proof surface.

2. *The ideal surface for tar surfacing.*—The water bound metalled surface to be treated shall be true to camber, free of pot holes, ruts and other defects, such as dusty or wet patches. In renewing metalling no earth or sand shall be used as a binding material and the consolidation shall be carefully executed so as to present as smooth and even a surface as possible, with the metal well compacted.

Stone that produces a " Glossy " or very glazed surface on fracture shall be avoided for use as metal. The best water bound macadam for tar surfacing is produced by the use of Pathankot or Jammu quartzite blinded with hard boulder lime stone bajri ; but when the latter is not available, lime stone bajri thoroughly clean and free of dust obtained from scarifying the lime stone metalling may be used.

3. *Dust and Dampness.*—These two factors are the greatest enemies of this class of work and shall be rigidly avoided and guarded against ; as any dust or dampness in the surface to be tar surfaced will spell disaster.

4. *Heating the Tar.*—The most rigid precautions shall be taken to see that neither " overheating " or " under heating " is allowed, either during the actual heating or when applying the tar. The temperature to which the tar is to be heated as specified by the manufacturers shall be strictly observed and adopted, and for this purpose heating plant shall carry, as accessories, at least two suitable thermometers for the regular testing of the heating.

5. *Plant.*—Suitable and sufficient tar heaters, sprayers, measures, spreaders, squeegees, straight edges, templates, cords, barriers, brushes (hard and soft), shall be duly arranged and collected at site, before the actual heating of the tar is commenced.

6. *General working instructions.*

(*a*) Sufficient materials and plant having been collected at site, carefully examine metalled surface to be treated for minor depressions and irregularities which need filling up and bring them up to the desired level and surface with bajri and tar (applied hot) consolidated with hand rammers.

(*b*) The berms having been repaired and brought up to full formation level and template (except when there are reasons that this shall be done after tar surfacing), and having arranged for the passage of traffic either along the berms or along a temporary diversion for the period the tar surfacing is in progress, place road-closed barriers to enclose one furlong of the road, and then thoroughly water the berms to lay the dust, and then keep watered to ensure that no dust lies on the surface to be treated, or on the newly laid tar surfacing. On completion of the tar surfacing in that furlong repeat this operation to end of work, opening out the completed lengths to traffic as soon as the tar has set sufficiently.

(*c*) The tar surfacing opened to traffic shall be carefully examined next day and any minor defects such as " sweating of tar " or " hungry patches " shall be corrected, the former by the sprinkling of a little fine bajri rammed with hand rammers the latter by the application of a little more heated tar sprinkled with a little fine bajri and then rammed, care being taken that neither process causes any humping or elevation out of the true template and camber of the road.

(d) In the case of renewal of old tar surfacing, or what is commonly known as the second or subsequent coats, all scaly or detached patches must be carefully removed and repairs executed as indicated in paras. (a) and (c) above, before the renewal coat is started.

(e) No sand shall be used in tar surfacing or in repairing the same.

7. *Application of tar surfacing using Shalimar No. 2.*—After compliance with the foregoing instructions thoroughly clean the surface to be treated, with hard and soft brushes to remove all dust, dung, mud and other matter that may impair the adhesive action and properties of the tar. Heat the tar gradually to 250°F. and maintain temperature while applying to the surface, mark out the extent to which the quality of tar is to be spread according to the capacity of the tar-pouring bucket in use, so as to ensure that an average of 0·25 hundredweight of tar shall cover 100 square feet of road surface. The pouring of the tar shall be started at the ridge, or highest point of the camber and continued to the edge, and care shall be taken that the whole metalled width is covered and that no tar goes to waste on the berms and that the edges are straight and not ragged. Spreaders of squeegees shall then be applied so that a coat of even thickness of tar is ensured, when the gritting, which shall consist of ½ inch to ⅛ inch gauge bajri (Haro river shingle) shall be done by means of " spraying " or " throwing " the grit in an even thickness over the coat of tar into which it will sink and to an extent that will form a compact conglomerate after rolling. The average amount of such grit shall be about 2 cubic feet per 100 square feet treated, provided at all times that no " sweating " or " Hungry patches " shall occur. Rolling with a light steam road roller shall be started and continued until the tar and grit form a compact mass as a true conglomerate. As soon as this tar surfacing has set sufficiently, traffic may be allowed over it and the work completed as under paragraph (6).

8. *Second and subsequent coats.*—The operations shall be the same as for the first or initial coats except that in place of 0·25 hundredweight of tar, the average amount will be, 0·1 hundredweight per 100 square feet and the grit shall be ¼ inch to ⅛ inch or course-clean Haro shingle. The average amount of such fine grit or sand shall be about one cubic foot per 100 square feet.

9. *Rates and conditions*—

(a) The rates include all cost for finished work, but the steam road rollers, template road barriers and tar boilers will be supplied on loan free of charge by Government at the nearest godown or storage place and the contractor will arrange his own carriage to and from work and will return them in the condition they were supplied, excepting for fair wear and tear. The running expenses of Steam Road Roller including the work charged establishment employed on same shall be recovered from the contractor from the day he takes it over to the day he returns it.

(b) Any temporary diversion necessary to keep traffic off the berms shall, if directed by the officer-in-charge, be made and maintained by the contractor on terms that shall be approved in advance.

(c) The tar shall be supplied to the contractor at Rs. 132 per ton inclusive of the drums free on rail at nearest railway station or storage area that serves the miles to be treated. If these are more than 8 miles distance from the miles to be treated the contractor will be paid carriage at the rates agreed for the extra leads beyond 8 miles. The contractor shall be responsible for all leakages that may occur during his handling the tar. If the tar is delivered to the contractor at roadside then the cost of carriage for the whole lead shall be recovered from the contractor at the rates entered for carriage in the agreements less the contractor's abatement.

(d) The tendered abatement shall be levied on all the rates included in the contract.

(e) The number of miles entered for the treatment in the contract shall be subject to alteration as may be found necessary.

Mr. S. G. Stubbs (the Author): Mr. Chairman and gentlemen: Both Mr. Trevor-Jones' paper and mine were written for the International Road Congress and have merely outlined what was done in the Punjab and indicate what we hope to do in the future and they are in no sense a thesis on roads. I have little to add to what has been said in these papers but as far as my own paper is concerned, I would like to emphasise that opinions expressed in it are my own based on my own personal experience and are not the considered opinions of the Local Government or of the Chief Engineer. There has been some misapprehension about the specification which has been described by me as water-bound premix which is referred to in my paper and which was criticised yesterday. This misconception will partly be removed when I say that the specification is water-bound premix and not mud-bound premix, the process merely consisting of spreading a 2-inch tar or bitumen carpet on to water-bound road. The greatest care is needed in the preparation of the base upon which the carpet is to be laid. The base must be firm and stable but unblinded and the surface of sufficient open texture to permit the carpet to key on to it. The object of water is to facilitate interlocking but it should not be used in excess otherwise mud is bound to be forced into the carpet with disastrous results. Some 20 miles of this specification has been laid in my circle and there is only one case of failure and that was on the Kalka-Simla road, about 5 miles from Simla. The chief reason of this failure was due to the fact that traffic was not kept off the base during the construction and thus interlocking was impossible. Besides, the metal and chips in this particular section of the road are very soft and are easily crushed. It is really impossible to lay any sort of carpet under those conditions. This specification has been described as unscientific This description is far from accurate. It is no less scientific than most other carpets which are just as likely to fail if they are not properly laid. Best results have been obtained from this specification on Kankar roads where complete grafting is effected. That is all I have to say at the moment.

The following paper was also submitted for discussion.

(*Paper No. 6.*)

ASPHALT ROADS.

By G. G. O. Adami, B.A. (Cantab.).

(*Burmah Shell Oil Storage and Distributing Company of India, Ltd.*)

1. The intention of this paper is to present a brief account of the development of the various types of Asphalt Road Specifications that have been laid or are now under trial in India. The underlying reasons for the development of such types of construction will be discussed and an endeavour made to explain where they have succeeded or failed to meet certain conditions which are typical of India as a whole or are peculiar to certain parts of India only. This entails some consideration of the factors which control the selection of suitable specifications, factors such as type and intensity of Traffic, availability of suitable materials, economic considerations, etc.

2. An attempt is also made to indicate the types of construction which appear most promising as solutions of road surfacing problems in India and which deserve prior consideration in experimental works to be carried out in the near future.

3. This is the first Indian Roads Congress and therefore, reference cannot be made to earlier papers dealing with the basic theories and facts of the technique of Asphalt road construction. Since, however, a true appreciation of the functions of the stone and the binder is essential to a proper understanding of what follows, it is necessary that these should first be recapitulated albeit as briefly as possible.

4. *Function of the stone.*—Stone is the traditional road building material and probably will always remain so; it is the Stone which carries the traffic and, hence, all other things being equal, the hardest and toughest stone will make the best road. As will be shown later, the most important consideration in the selection of a suitable specification for given traffic conditions concerns the quality of the available stone; the importance of this consideration is obvious in view of the fact that it is the stone which is going to provide the wearing quality of the road.

5. The Stones form the weight carrying skeleton but they require to be keyed tightly together to provide lateral stability otherwise they will ravel. The Romans obtained lateral stability by using dressed stones, such as Stone-Sets, etc., which fitted tightly together and prevented movement but their cost to-day is prohibitive, except under special circumstances, especially in view of the fact that they require a rigid foundation to provide a smooth surface. Macadam discovered that if small fragments of stone, broken to different sizes and of irregular shape were spread and forced tightly together under a heavy roller, they would key together and provide sufficient inherent stability, through interlocking, to meet the requirements of the traffic of his day.

6. His theory amounted, in fact, to the reconstruction of the solid rock by the use of stones of different sizes in such proportions that the smaller stones would fit into the spaces between the larger stones and, by

fitting tightly and having their own voids filled with still smaller fragments, would wedge the interlocked stones firmly into position and prevent their displacement under traffic stresses. The inherent stability of the mass is dependent on the interlocking which, in turn, is maintained by the wedging of the smaller fragments; so soon, however, as the stones are free to move through displacement of the wedging material or are forced to move under heavy loads, there is no stability and the road disintegrates.

7. This theory is still the fundamental basis of nearly every type of road construction. Macadam used water to wash his very smallest wedges into position while to-day a binder, Asphalt, Tar or Cement, is generally used to reinforce the interlock and prevent movement and displacement.

8. *Function of the Asphalt.*—The interlocking of the stone on a road can be destroyed in two ways, namely (*a*) by the wedging material between the interlocked stones being removed, in which case there is no lateral support for the interlocked stones and they move out of position, and (*b*) loads which are greater than the inherent stability of the wedged and interlocked stones can carry; such loads by sheer magnitude force the stones and their wedges apart and disrupt the interlock.

9. Briefly (*a*) is caused by fast traffic, the wheels of which suck the wedging material from out between the stones on the surface sun, wind and rain also help to dislodge this material. In (*a*), therefore, disintegration commences on the surface and gradually works downwards. In the case of (*b*) the damage is generally due by slow moving, narrow iron tyres; the small bearing surface of the narrow rim intensifies the load and disrupts the interlock by sheer weight.

10. A combination of (*a*) and (*b*), that is a road carrying mixed traffic is the most disastrous, for the fast traffic loosens the surface for the iron tyres to break up.

11. The cure for (*a*) is to treat the surface of the road with some material which will form a protective skin and so prevent the wedging material being removed. Such a skin must be impervious to rain and moisture, must not "weather", and must be sufficiently tough to resist wear from traffic using the road for, the moment the skin is broken, the material wedging the stone into position is exposed, liable to be removed and so allows the commencement of disintegration. This type of treatment is known as surface treatment.

12. In the case of (*b*), in order to strengthen the wedging effect of the smaller stones and help to keep them and the large stones from being disrupted, a binder, Asphalt, is introduced into the road itself and which, through its binding powers, will hold the stones together and prevent their displacement.

13. *Two main types of Asphalt construction.*—It will be appreciated from the foregoing, therefore, that there are two main types of Asphalt construction, namely (1) the protection of the surface of the road only and (2) the incorporation of the Asphalt into the body of the road itself to increase the resistance of the stone to displacement from traffic stresses. There are, of course, a great many varieties of these two main types.

14. *Types of construction used in India up to 1930.*—In India, up to 1930, outside one or two large cities and some special works such as the Cawnpore-Jhansi Road and the Nili Bar Project there were only two types of Asphalt construction used, namely, Single and Double Coat Surface Dressing for light traffic roads, and Grouting or Semi-Grouting for medium and heavy traffic roads. The former merely consisted of the spreading of a thin layer of Asphalt in either one or two coats on the surface of the road and blinding with stone or bajri chips. The latter was an attempt to incorporate the Asphalt into the body of the road by first spreading the stones and then pouring the Asphalt over them so that it would trickle down and coat all the stones. Either Hot Asphalt or Emulsified Asphalt was used.

15. This period was devoid of any experiments with new specifications and really amounted to being a period during which Indian conditions were being watched and the defects of these methods to meet local conditions studied with a view to ascertaining what would be the most promising line of experiment.

16. *Criticism of Single Coat Surface Dressing.*—The scope of Single Coat Surface Dressing has been found to be definitely limited under the following headings:—

(1) A Single Coat of Surface Dressing requires to be laid on a well consolidated macadam road, or a surface which contains plenty of firmly embedded metal or gravel. otherwise a priming coat is required which adds to the cost.

(2) Since a Single Coat Surface Dressing is usually carried out at not more than 1/3rd gallon per sq. yd. the film deposited is thin and, therefore, the contour of the treated surface will conform to that of the base. Hence if a smooth, true surface is required, it is necessary first to re-section the base. This means that the salvage value of an old road often has to be sacrificed, besides the expense of re-sectioning.

(3) The film of Asphalt being thin it can only be expected, in all fairness, to carry motor traffic with a very minimum of iron tyred traffic. Iron tyres quickly cut through the very thin film.

(4) The argument is advanced that, because a Single Coat Surface Dressing is initially inexpensive and the cost of repainting low, it is cheapest in the long run to lay a single coat and repaint from year to year or every two years or three years depending on the volume of traffic. The effect, however, of repainting is eventually to build up a thick mat which is excessively rich in bitumen and will wave and corrugate under traffic.

17. *Recommendation.*—Single Coat Surface Dressing should only be used in cases where traffic consists of rubber tyred vehicles with only a very small percentage of light iron tyred traffic. Single Coat Surface Dressing is the cheapest type of Asphalt construction and is of definite value on certain light trafficked roads such as Cantonment and purely residential roads where iron tyred traffic is largely excluded. If it is found that a single coat will not last more than two years without repainting then an alternative type of construction should be considered as is recommended further on.

18. *Criticism of two coat surface dressing.*—(1) Whereas by using a large size stone ½" to ¾" for blinding the first application of the Asphalt, an appreciably thick mat can be built up which will cope with certain unevennesses of the base, it is generally necessary to re-section the base before laying the dressing. This costs money as well as losing the salvage value of the old base.

19. (2) An excessive quantity of Asphalt has to be used in two-coat surface dressing even to obtain the ½" to ¾" thickness of the construction. Allowing a first application of ¼ gallon per sq. yd. and a second of 1/3rd gallon and blindage at 4 and 3 cub. ft. per 100 sq. ft. it means that approximately 65 lbs. of Asphalt are required to coat and absorb say 7 cub. ft. of stone or a little more than 9 lbs. per cub. ft. By methods described later on, it would be possible to coat 20 cub. ft. of stone with the same quantity of Asphalt and so build up at least a 1½" thick mat. The method therefore is most uneconomical.

20. (3) Although this method gives a stronger surface than single coat, it is not strong enough to carry any appreciable volume of iron tyred traffic.

21. *Recommendation.*—Two coat surface dressing should be discontinued for it is a most uneconomical type of construction and does not give value for money.

22. *Criticism of grouting methods.*—As already pointed out, Grouting or Semi-Grouting was employed universally in India prior to 1930 for heavy traffic or medium heavy traffic. Whereas very satisfactory results have been obtained with this method on all except very heavy trafficked roads it has two serious defects; namely, that it is a wastefully expensive method and also that it can never hope to cope with really heavy traffic. The reason for both these defects is the same, namely, that an excess of Asphalt has to be used; that is to say an excess as compared to other methods. In the grouting or penetration methods the stone is first spread on the road and the Asphalt poured over it in order that it may flow down through the interstices and reach and coat the lowest layer of stone. In the case of Hot Asphalts, the interstices between the stones have to be left rather wide so as not to impede the flow of the quickly cooling Asphalt and hence, apart from the excess of Asphalt due to the fact that some goes merely to fill the voids, there is no great density of stone since the use of small stone would block the interstices. With Asphalt emulsions matters are improved because the emulsion, being applied cold and of low viscosity, will flow down through comparatively small interstices and therefore a dense graded stone can be used.

23. Generally speaking, a 2½" consolidated grout requires at least 1¼ gallon per sq. yd. for the grouting, exclusive of the subsequent seal. Allowing 25 cub. ft. of stone per 100 sq. ft. this means 5·6 lbs. of Asphalt per cub. ft. By other methods not more than 3·5 lbs would be required and a saving of 5 gallons per 100 sq. ft. effected. The same quantity of emulsion would be required as of Hot Asphalt at least and, although the quantity of bitumen deposited would be less, there would still be the extra cost, because of the extra 5 gallons of emulsion used for 100 sq. ft.

24. The same arguments apply in the case of a Semi Grout.

25. *Conclusion.*—The Grouting Penetration method is a thoroughly uneconomical method apart from the fact that it does not provide the same strength as other methods which are to be described; in fact the excess of binder which makes it uneconomical also is detrimental to the strength for it acts as a lubricator and, under heavy traffic, waving occurs. Grouting is now almost entirely discontinued in India.

26. *Trend of specifications since 1930.*—Since 1930, experimentation has been carried out, both officially and by those commercially interested, with a view to finding suitable specifications which will allow not only the laying of a denser and, therefore, stronger mat but also a reduction in costs by using less bitumen. The obvious means of achieving these was to precoat the stones before laying it on the road. Hence experiments have almost entirely been directed in this direction: there have also been experiments whose object was to increase the density without materially reducing the quantity of binder, but in such cases there have been extraneous circumstances which enabled savings to be effected in other directions than in the saving of binder. Armour Coat and retreads are examples of this. These will be dealt with later.

27. *Advantages of pre-coating aggregate.*—Briefly, as already stated, the advantages of pre-coating the aggregate are (1) a very densely graded aggregate can be used (2) pre-coating allows the provision of the thinnest film of binder consonant with maximum binding, (3) by using a thin film of binder there is a saving in cost through reduction in the quantity of binder required and (4) danger of rutting or waving under traffic is avoided if there is no excess of binder.

(I) As has been stated under "Function of Stone" the ideal is to reconstruct the solid rock and, therefore, the denser the mat the stronger it will be. In order to attain maximum density it is necessary that there should be a minimum of voids and hence a densely graded aggregate should contain fragments of stone varying in size in their correct proportions from 1½" to 2" right down to fine sand or filler. The proportions of each size required can be found by calculating the percentage of voids in each gauge of stone and using only so much of the smaller size as will fill the voids in the size above. It can easily be appreciated that to coat each particle of such a densely graded aggregate by first spreading the aggregate on the road and pouring Asphalt over it is out of the question, coating alone can be effected by mixing with Asphalt in suitable mixers before being spread on the road.

(II) By mixing the aggregate and binder together in a suitable mixing arrangement it is possible to ensure that every particle of aggregate is coated with a uniform film of binder and that the thickness is only so great as will provide a maximum bind.

28. *Special quality of binder required for pre-mixing.*—In order to coat an aggregate with a binder it is necessary that the binder should be of sufficiently low viscosity during the mixing operation to allow a thin coating of binder to be given to each particle of aggregate. (The question of emulsions for this purpose will be dealt with further on; the following remarks deal with Hot Asphalts). If an ordinary straight Hot Asphalt were to be brought into contact with a cold aggregate, it would immediately thicken and become too viscous for mixing. It is obvious, therefore, to

pre-coat an aggregate it is necessary either to heat the stone to the same temperature as the Asphalt or, treat the Asphalt in some way that it will not be too viscous when it is mixed with the cold stone. The former is known as Hot-Mix and the latter, for want of a better name, will here be called Cold Mix although it is only the stone which is cold.

29. *Hot-Mix.*—Until comparatively recently all pre-mix work was done on the Hot-Mix principle. But to heat the stone to the same temperature as the Asphalt requires a very large, expensive and cumbersome plant which at the best can only be semi-stationary. Such a plant, therefore, can only be justified where there is annually a large programme of pre-mix within a radius of a few miles of the depôt in which the plant is situated. It is only in large Municipalities such as Bombay, Calcutta, Madras, etc., that such a state of affairs exists and the establishment of a hot mix plant is justified. As this paper is chiefly concerned with road work outside Municipalities it is not necessary to make further reference to Hot-Mix. In view of recent developments in cold mix methods there really is not now any advantage in the Hot-Mix method except perhaps in dealing with sheet asphalt; probably a rather thinner film can be given with hot-mix than cold mix and so shows some saving in cost, otherwise there are few real advantages. The cost and bulk of the plant puts it out of consideration for works in India outside the Municipalities.

30. *Cold Mix.*—Here the stone is used cold and the Asphalt has to be specially treated so that it does not become too viscous during the mixing operation. This is achieved by adding a solvent, generally of the Kerosene or Gas Oil type to the Asphalt. This is known as Cutting Back and has the effect of thinning the Asphalt so that it remains of low viscosity even at comparatively low temperatures. After spreading on the road and consolidation the solvent goes off leaving the Asphalt of its original penetration. The quantity of solvent used which is one of the most important considerations depends on a number of factors which are discussed fully under different heads. The more solvent that is used, the easier is the mixing but the longer will the road take to harden up or "Set".

31. *Emulsion Mixes.*—Emulsions are of low viscosity at normal temperatures and therefore there is no question of thickening from the temperature point of view. But there are two important considerations in regard to emulsions for mixing purposes, namely (1) rate of break and (2) viscosity.

(1) *"Rate of Break".*—Normal emulsions are of the "quick break" variety and, if they were used for mixing with aggregates consisting of graded particles, they would break almost immediately; the Asphalt would coagulate and there would be no proper coating. The greater the percentage of fines in the aggregate, the greater is the effect of breaking the emulsion. The mixing of graded aggregates necessitates the use of a "slow break" or stable type of emulsion.

(2) *Viscosity.*—Consideration has to be given to the viscosity of the emulsion in pre-mixing. A coarse aggregate requires a more viscous emulsion than a fine aggregate, such as sand, because, if the emulsion is too thin it tends to flow freely off the big stones before depositing a thick enough film of Asphalt. To coat fines it is necessary to have a thin emulsion and the viscosity is often reduced below normal by dilution.

These factors require special attention and different combinations of coarse and fine aggregates require different viscosities of emulsion; this is usually done by manipulating the viscosity by dilution with water.

32. *Plant required for pre-mixing.*—It has already been mentioned that Hot-Mix requires an expensive plant costing at least Rs. 50,000, in order to heat the stone; the following applies, therefore, to the cold mix types.

33. *Cut-Backs.*—The plant for mixing the aggregate and the cut-back depends very largely on the percentage of solvent in the cut-back. A heavily cut-back Asphalt mixes easily and mixing can be carried out either by hand, in a concrete mixer or in oscillating or revolving 40-gallon drums. When the solvent content does not exceed 10 per cent. the asphalt would be too stiff to mix easily and a pug-mill type of mixer is required.

34. The question of plant is an important one and will be mentioned again later for it enters the discussion on the question whether a quick-set road, which entails relatively costly plant, is of greater demand than a slow set road which requires cheap plant.

35. Actually, apart from the initial cost of about Rs. 6,000 for a pug-mill type of mixer, such a mixer will turn out 150 to 200 batches a day, each of 5 cub. ft. capacity, making an output of 750 to 1,000 cub. ft. per day. An oscillating drum at the very most will turn out 100 cub. ft. and, therefore, 8 to 10 drums are required for the output of one mixer. This, however is all referred to hereafter in greater detail.

36. *Emulsion.*—Owing to the low viscosity of emulsions mixing can be done by hand, in drums or in a concrete mixer and no difficulties apart from the adjustment of the viscosity generally arise. A stable emulsion therefore has a distinct advantage over cut-backs from the point of view of ease of mixing by hand, although if done in a mixer the out-put would be scarcely greater than in the case of cut-backs.

37. *Dipping Process.*—Mention must be made here to the Dipping Process as a means of coating aggregates with emulsions. By this process the aggregate is placed in a perforated bucket and dipped into the emulsion until all particles have come into contact with the emulsion. Excess is then allowed to drain off and the coated aggregate spread on the road. The purpose of the Dipping Process is to avoid the stone coming in violent contact with the emulsion, as would occur in ordinary mixing, and so cause the emulsion, which is not a stable one, to break; in other words it is used in cases where it is desired to obtain a pre-coated effect with a quick-break, unstable emulsion. Further reference is made to this process.

38. *Types of pre-mix.*—There are three main divisions of pre-mixes available for road construction purposes in India :—

1. The concrete type—Asphaltic concrete.
2. The Macadam type—Asphalt Macadam.
3. The Sheet or sand carpet type.

It is necessary to explain these in some detail for a thorough understanding is essential when considering the most suitable types of construction for certain conditions of traffic, aggregate, etc.

39. *The concrete type.*—The concrete type aims at density and, therefore, the aggregate generally consists of coarse and fine aggregates in such proportion that there is a minimum of voids. The types of aggregate used

consists of stone, chippings, sand and filler, the intention being that the chippings fill the voids in the stone, the sand the voids in the chippings and the filler the voids in the sand. The theoretical proportion of each of these different sized fragments can easily be calculated by measuring the voids in each of the different sizes: theoretically, therefore, it is possible to produce a voidless mass for the binder will fill the voids in the filler. All orthodox text books on the subject of the design of asphaltic concrete emphasise this necessity for density by the use of a very carefully graded aggregate and all hot-mix asphaltic concrete jobs follow this theory religiously. What follows is a personal opinion but, although it is rather against all orthodox theories on the subject, the opinion has been developed during a very close study of the behaviour of asphaltic concrete roads in India and experience with constructions following this new theory has been amply justified.

40. While there is no question as to the soundness and correctness of the *theory* of eliminating voids by the use of a carefully graded aggregate, there is a very great difficulty when it comes to practice. The quantity of each sized aggregate can be determined easily and correctly enough by measuring the total of the voids in the stone whose voids are to be filled, but it is impossible to measure the size and shape of the individual voids into which the individual fragments of stone are to fit, for instance, suppose the largest size stone to be used is of $1\frac{1}{2}''$ to $2''$ gauge and the volume of voids in it found to be 45 per cent then, according to the theory, the quantity of the next size should be 45 per cent less the volume of asphalt required to coat the large stone and intermediate stone. But neither the theory nor the void test gives any indication as to what size of stone should be used for the purpose. Herein lies the difficulty for obviously, if too large a stone is used, instead of fitting into the void formed by the interlocked larger size stone, it will prevent the larger stone from interlocking tightly together. A further difficulty in practice is that while it is simple enough to put the ingredients into the mixer in their proper proportions, when the mix comes out, especially after spreading on the road, there is no means to ensure a uniform distribution of the ingredients on the road: in other words to prevent segregation. If there is segregation then all the toil and trouble of calculating voids, etc. is of no avail.

41. It must be remembered that the strength of the mat is dependent on the interlocking of the large stone and that the purpose of the smaller fragments is to fill up the space between these large stone and prevent their moving; if the effect in practice on the road is for the intermediate fragments to tend to get between the large fragments and interfere with the interlock, they are doing more harm than good. There have been cases in India, the asphaltic concrete on the Cawnpore-Jhansi road laid in 1925 being an example, where a most carefully graded asphaltic concrete containing the minimum of voids and the correct percentage of binder has eventually tracked under concentrated bullock cart traffic; similar cases have also occurred in Bombay and Calcutta. Investigations have shown that there was nothing at fault with the grading of the aggregate and that the correct penetration of binder had been used; it was noticed that the tracking only occurred where there was very heavy iron tyred traffic which followed in its own tracks. Gradually the theory was evolved that the tyres were breaking the interlock of the stones and pushing them apart; the interlock-

not being as effective as it should have been to withstand such severe traffic. It soon became obvious that it was necessary to alter the design so as to eliminate any factors which might be tending to interfere with the interlock. Eventually a solution was found and which has proved itself under the most concentrated iron tyred traffic. This was to eliminate the intermediate sized fragments altogether and to use only a mixture of large stone and sand. The advantages of this procedure are that there is nothing, provided the correct quantity of sand is used, to prevent the interlock of the large stone and that therefore maximum interlock is assured. A mixture of sand and asphalt makes a good mastic and this mastic will easily fill into the voids and mould itself to the exact shape of the voids so that they are exactly filled After the set of the asphalt this mastic sets very hard and so effectively locks the large stone into position. It is recommended, therefore, that whenever an asphaltic concrete tyre of construction is to be used in India the aggregate should consist only of the largest sized stone consonant with the thickness of the finished carpet. say, two-thirds, and a medium sand, sufficient in quantity to fill the voids in the stone with no excess to cause bulking. Stone generally has about 45 per cent of voids and so allowing a small excess of sand to fill the surface voids and form a seal the usual proportions recommended are 2 parts by volume of stone to one part of sand. Using a cut-back with a solvent content of less than 8 per cent. to ensure a quick set-up on the road, the quantity of asphalt required to coat the stone is 3 to 3½ lbs. per loose cub. ft. while the sand requires 6 to 9 lbs. per cub. ft. dependent upon its fineness.

42. In designing this improved form of asphaltic concrete it was also necessary to devise a means whereby there would be no segregation of the stone and sand at the time of spreading. This was obtained by first coating the stone with an excessively heavy coat of asphalt and then adding the sand after which a further small quantity of asphalt was added; the effect was that the sand adhered to the stone which was coated with the excess of asphalt and so was distributed evenly throughout the mix, each stone carrying sufficient sand round it to fill the void between it and the other stones when forced tight against them under the roller. The sand at the time of mixing being a malleable mastic easily moulds itself to the shape of the voids. There is one point of importance to be remembered in this technique and that is that the asphalt used must be rather viscous at the time of mixing otherwise it will not hold the sand to the stone and there will be some segregation; it has been found that a cut-back with not more than 8 per cent of solvent has the requisite viscosity.

43. Summarising, the type of asphaltic concrete recommended for India is that the aggregate should consist of large stone and sand only, there being only sufficient sand to fill to the voids in the stone and provide a thin seal. The asphalt at the time of mixing should be sufficiently viscous to hold the sand to the coated stone. The mixing procedure should be first to coat the stone with two-thirds of the total asphalt required, then add the sand and continue mixing until it all adheres to the stone and then, finally, add the balance of the asphalt.

44. *Macadam type.*—The macadam type makes use of stone only and the large stones are held in place with smaller stones, no sand being incorporated. This type of construction therefore is not so dense as the concrete type and so not so well capable of carrying heavy iron tyred

traffic. In view of the fact that it contains no sand, considerably less asphalt is required and it is therefore a cheaper type of construction. Asphalt macadam consists of a base course and a surfacing course, the latter being required because there are more open voids on the surface through the omission of sand; the surfacing course may either be of coated chippings or of a liquid seal.

Base Course.—This consists of two sizes of stone, a large stone which provides the interlock and a small stone to wedge the large stone into position. Here again there is danger of the smaller stones interfering with the interlock and they should be used rather sparingly especially if the surfacing course is to consist of coated chips. Generally speaking, if the available stone is of good hard quality, the composition of the base course should be about 65 per cent of large stone and 35 per cent of the small. The quantity of asphalt that the stone requires is 3 to 3½ lbs. per cub. ft. It should be explained here that there is not the same concern with regard to the smaller stone interfering with the interlock of the large stone as in the case of the concrete types because the macadam construction is not generally used for such heavy traffic and so can better afford a slight interference with the interlock.

Surfacing Course.—As already mentioned there are two types of surfacing course and these are explained below.

Liquid Seal.—After the base course has been spread and rolled, the surface is blinded with dry chippings at about 4 cub. ft. per 100 sq. ft. and rolled again. The object of these dry chips is to fill the surface voids and help to key the stone in the surface into position. A seal is then applied at about ¼ gallon per sq. yd. and blinded with fine chippings.

Mixed Chip Seal.—In this method as soon the base course is spread and rolled ½ to ⅛th inch chippings coated with Asphalt at the rate of 3½ to 4 lbs. of asphalt per cub. ft. are laid at the rate of 6 cub. ft. per 100 sq. ft. and rolled well into the base course. There is really little to choose between the mixed and the liquid seal. The former requires from 21 to 24 lbs. of asphalt per 100 sq. ft. while the latter takes about 30 lbs. but, if the work is to be done shortly before rain is expected, or if there is not much fast traffic on the road to help to seal the coated chips, it is wiser generally to use the liquid seal which ensures a complete seal immediately.

45. *Sheet Asphalt Type.*—Strictly speaking, the sheet asphalt type of construction uses sand only and is not usually laid to a greater depth than 2″. A sand carpet has a very smooth surface immediately after rolling and does not require to be polished by traffic. It is of particular value for foot paths, drivers, etc., but it is also proving very successful for medium trafficked roads in India and will carry appreciable iron tyred traffic. In India this sand carpet has been amended to meet certain local conditions. In many parts of India broken stone is not only expensive and difficult to procure, especially in the smaller sizes, but the quality of the stone is unsuitable for road purposes, whereas sand is plentiful and cheap. A sand carpet therefore is invaluable in many parts of India and will give better results than a stone road. The great disadvantage of a sand carpet is, however, that the sand requires from 6 to 9 lbs. of Asphalt to the cub. ft. to coat it and, therefore, the cost is

excessive. To get over this difficulty in India stone is added to the sand but only in such proportions that the stone is not the weight carrying skeleton; the sole function of the stone is to take up space, displace some of the sand and so reduce the quantity of asphalt required. The usual proportions are equal volumes of stone and sand; with this proportion of stone there is no question of the stone interlocking and carrying the wear of the traffic. it is merely embeded in the sand and taking up space. Therefore, provided the stone is not as soft as *kunkar*, which would crush under the initial rolling and leave uncoated patches in the carpet, any kind of stone or gravel will serve the purpose. This type of construction is being found of great value in many parts of India where the quality of available stone is bad.

46. The mixing operation follows that of the concrete type, that is to say the stone is first coated and the sand added after, but in this case the purpose of the sequence is not so much as to cause the sand to adhere to the stone and so prevent segregation as to ensure that the stone does get some coating; if the stone and sand were fed in together the sand would absorb all the asphalt and leave the stone entirely uncoated. There is one other point of importance and that is that only 2½ lbs. of asphalt per cub. ft. are allowed for the stone as against the 3 to 3½ lbs. allowed in the other type, the reason for this is that as the stone only acts as a space filler to displace sand. it does not require the same thickness of film.

47. The saving in asphalt obtained by adding the stone is very considerable, for instance, for a 1½ inch consolidated thickness 16 cub. ft. per 100 sq. ft. of sand would be required which at 9 lbs. per cub. ft. would amount to 144 lbs. By using 8 cub. ft. of sand and 8 cub. ft. of stone at 9 lbs. and 2½ lbs. per cub ft. respectively only 92 lbs. of asphalt would be required.

48. *Armour Coat Retread Methods.*—The three types of construction described above are best suited to cut-backs. It is possible to make these pre-mixes with emulsions, especially the macadam type provided a suitable stable emulsion is used. When it comes to incorporating sand or other fines in conjunction with coarse stone, difficulties arise over viscosities, etc., and very skilled supervision is required for each and every job. When, therefore, an emulsion is desired to be used and the same extent of density obtained on the road, a special type of construction is generally used which avoids the actual pre-mixing; these are given a variety of names but they are all very similar whether they are Armour-coat, Built-up-mat, Retread, etc.

49. In these types of construction the largest sized stone is first spread on the road and some fines scattered over them so that they fall into the voids. An application of emulsion is then given and an intermediate size stone scattered on so as to go into the voids of the stone. The fines which were first scattered on, were not intended to fill the voids but merely to be there so that when the intermediate stone was spread they would, in combination with them, help to fill the voids. After the intermediate stone has been spread another application of the emulsion is made and blinded with still smaller stone. So the operation goes on using every

size of stone in turn and making an application of emulsion after each application. By this method it is possible to build up a very dense mat consisting of stone and sand and it can be built to any required thickness. No plant except sprayers with which to apply the emulsion are required. The only comments adverse to the method are that a range of graded stone is required and that rather more emulsion has to be used than in the case of pre-mixing. It builds, however, a good strong carpet provided the available stone is strong and tough. Further reference is made to this method later.

50. The above describes the main types of construction with which experiments have been carried out during the past four years; the experiments have of course covered many varieties of these types as well as means of pre-mixing such as plant pre-mix, drum pre-mix, grader pre-mix, etc. Experiments also covered the thickness required for various traffic conditions as well as the applicability of the methods to locally available materials. It is impossible to go into all these here but the results of the experiments are referred to later in the discussion on the suitability of certain specifications to given conditions. It is absolutely necessary, however, to appreciate and understand the underlying principles of the main types of construction described above otherwise it is impossible to decide on the best specification to use for any road job; it has therefore been necessary to treat them at some length and in some detail.

51. *Thickness of carpets required in India.*—Experience has indicated that three thicknesses of carpet are required for India; these are, Single Coat Surface Dressing, 1 to 1½″ consolidated thickness and 2 to 3″ thickness. Of these, as will be explained, the 1 to 1½″ thickness has by far the greatest general utility.

52. *Single Coat Surface Dressing.*—This is the cheapest of all types of asphalt construction and is of great value under certain conditions. Its use should be confined to roads such as Cantonment roads, where iron tyred traffic is restricted to a very minimum. It must be appreciated that a Single Coat Surface Dressing is too thin to re-section a road and, therefore, it should only be used on surfaces which have previously been re-sectioned. A Surface Dressing may also serve a very useful purpose in another direction; in cases where a waterbound road has been completely re-made because its shape had passed re-sectioning by a 1½″ mat, it is usually advisable to allow consolidation under traffic for some months before a carpet is laid upon it, but, if there is much fast traffic on the road not only is the dust nuisance severe but the macadam may be damaged considerably during the consolidating period. If a Single Coat Surface Dressing were applied immediately after the re-making of the waterbound macadam, it will protect the waterbound macadam, hasten consolidation and prove an excellent base when it has worn out for the 1½″ carpet. It may be argued that this procedure entails extra cost but, the increased strength given to the base and the assurance of perfect consolidation will prove invaluable in the later history of the road.

53. *One inch to one-half inches consolidated thickness.*—This thickness of mat is of particular utility to India for two particular reasons, (a) it is

sufficiently thick to cope with most unevennesses on old roads and so obviates the re-making of the base and, (b) such a carpet is strong enough to cope with the traffic found on most roads in India for it will take appreciable iron tyred traffic, as much as is generally found on roads outside main cities; it can take an unlimited amount of pneumatic tyred traffic.

54. The most suitable specifications for the 1 to 1½" carpet are of the pre-mix type for they allow variations in the thickness to cope with inequalities without forming weak spots to a greater extent than other types of construction; for instance, in the Grouting methods or where the binder is applied after the stone has been spread, it is impossible to tell whether there is a greater or lesser thickness of stone over an inequality in the base after the stone has been spread, yet the binder is applied at the same rate over the whole, resulting in "fat" and "bare" patches.

55. *2" to 3" Thickness.*—Where traffic is very intense with a very high percentage of bullock carts, it is necessary to build up a thicker mat, the thickness being dependent upon the traffic. Generally speaking, such mats should not be more than 3" and 2½" is usually sufficient. The methods employed for these thicker mats are exactly the same as for the 1½" except that relatively larger stone is used.

56. *Gauge of stone to be used.*—In all road construction methods it is important that no stone should be so large or so shaped that when it is in position on the road it will be of the thickness of the mat and so, of itself bear the complete load of the traffic: no stone is hard or strong enough to do this. On the other hand, it should always be borne in mind that the greater the individual mass, the greater is the strength and, therefore, as large stone should be used as possible, consonant with the stipulation stated above In other words, the stone should be of such a size that everywhere they are two deep and not more on the road. Since it is impossible to obtain absolutely cubical stones and every stone will be somewhat flattened, it may be laid down that the maximum gauge of the stone should be not more nor less than 2/3rds of the thickness of the final consolidated mat.

57. *Selection of specifications.*—The selection of the proper specification for any road is primarily dependent on the traffic using the road and it is necessary to consider the suitability of the locally available aggregates from this point of view; for instance, if the traffic is only medium-heavy but the quality of the stone is poor, it is wiser to use an asphalt concrete type of construction rather than a macadam. A second consideration is cost and, if the traffic is light it is foolish to use a construction which is more expensive than is necessary; at the same time one type of aggregate, say, broken stone, may be so much more expensive than another, say, sand, that it is actually cheaper to use an asphaltic or sheet asphalt type of construction despite the extra quantity of Asphalt that may be required. It is necessary, therefore, to have a clear idea of the quantities and types of aggregate, as well as of binder, required for the various available Specifications; a table is given below which indicates these clearly for an area of 100 sq. ft.

Table showing quantities of materials required per 100 sq. ft. for different methods of construction laid to a consolidated thickness of 1½".

Method of Construction.	Aggregate.		Binder.		Average Binder per cub. ft. of Aggregate.
Single Coat Surface Dressing.	Blindage .	5 cub. ft.	@ 1/3 gal. per sq. yd. .	37·5 lbs.	7·5 lbs.
Asphaltic . .	Metal . .	15 cub. ft.	@ 3 1/3 lbs. per cub. ft. .	48 lbs.	5·33 lbs.
Concrete . .	Sand . .	7·5 ,,	@ 9* ,, ,, . .	67·5 ,,	
	Total .	22·5 cub. ft.	Total .	115·5 lbs.	
Asphaltic † . .	Metal . .	15 cub. ft.	@ 3 1/3 lbs. per cub. ft. .	48 lbs.	3·5 lbs.
Macadam . .	Chips . .	6 ,,	@ 4 1/2 ,, ,, ,, .	26 ,,	
Mixed Seal.	Total .	21 cub. ft.	Total .	74 lbs.	
Asphaltic . .	Metal . .	15 cub. ft.	@ 3 1/3 lbs. per cub. ft. .	48 lbs.	3·9 lbs.
Macadam . .	Chips . .	4 ,,	Seal @ 1/3 gal. per sq. yd.	37·5 ,,	
Liquid Seal . .	Blindage .	3 ,,			
	Total .	22 cub. ft.	Total .	85·5 lbs.	
Sheet Asphalt . .	Metal . .	8 cub. ft.	@ 2 1/2 lbs. per cub. ft. .	20 lbs.	5·75 lbs.
	Sand . .	8 ,,	@ 9* ,, ,, ,, .	72 ,,	
	Total .	16 cub. ft.	Total .	92 lbs.	
Armourcoat . .	Metal . .	10 cub. ft.	Tack Coat @ 1/5th gal. per sq. yd.	22 lbs.	6·1 lbs.
With Emulsion .	Chips . .	3 ,,	1st application @ 3/8th gal.	42 ,,	
	Grit . .	5 ,,	2nd application @ 3/8th gal.	42 ,,	
	Blindage .	3 ,,	Seal @ 1/5th gal. . .	22 ,,	
	Total .	21 cub. ft.	Total .	128 lbs.	

* This is the maximum : Sand takes between 6 to 9 lbs. per cub. ft., usually 7 to 8 lbs.

† If this type of construction is done just before the monsoon or if there is only a little pneumatic tyred traffic, it should be sealed with asphalt at 1/5th gallon per sq. yd. and blinded with *bajri* at 3 cub. ft. per 100 sq. ft. This alters the final figure to 4 lbs.

N.B.—Where emulsions are used the quantities required per cub. ft. of aggregate should be increased by 15 to 20 per cent.

58. *Traffic.*—Experience has shown that the various intensities of traffic shown below require the following types of construction:—

Heavy Bullock cart .. .	Asphaltic Concrete Type of Construction.
Medium Bullock Cart Heavy Motor Lorries.	Macadam Type of Construction Armour-coat.
Medium-Light Bullock Cart Heavy Motor Lorries.	Sheet Asphalt.
Medium Motor Traffic Light Bullock Carts.	Surface Dressing.

For heavy Bullock carts it is absolutely essential to have the densest possible mix so that the interlock cannot be disrupted by the loads and, therefore, the asphaltic concrete type of construction only should be used.

59. *Aggregate.*—The quality of the available aggregate plays a most important part in the selection of the specification; too frequently insufficient attention is given to the aggregate, and specifications are used which are unsuited to the quality of the stone.

60. A macadam type of construction should never be used unless the stone is of the very toughest variety or if the traffic is comparatively light; the reason for this is that however well graded a stone aggregate may be, it is not so dense as in the asphaltic concrete type and, if one of the larger stones fractures under a heavy vehicle, the stability of all the stones around it is upset because the interlock is weakened and a pot-hole quickly develops.

61. In the asphalt concrete type, however, the sand mastic fills the voids between the stones completely and sets so hard that even if a stone does fracture, the two parts of the stone cannot move apart and the stability is maintained. Stone such as is found in and around Delhi appears very hard but yet splinters and fractures easily under traffic and this is the reason why macadam types have not proved so satisfactory as the asphaltic concrete or Sheet Asphalt types. An examination of the surface of Hamilton Road will show a mosaic surface and it will be noticed that practically every stone that shows is badly splintered yet, because the sand mastic holds them together so tightly the whole stone is held together and not allowed to disintegrate. It is always advisable, therefore, when there is any doubt whatsoever over the quality of the stone, to use the asphaltic concrete type instead of the macadam.

62. The table above shows that actually there is very little difference in the cost of the two methods because although the asphaltic concrete type may use more asphalt in the main body, the macadam type requires a seal.

63. Where stone is definitely poor in quality then the Sheet asphalt type of construction should be used because the sand will take the wear of traffic and the stone has no other function than to take up space and effect a saving in the quantity of the binder required. The above may be summarised as follows:—

(1) The macadam types should only be used when the stone is of the very best quality.

(2) Where there is any doubt with regard to the stone then the asphaltic concrete specification should be used.

(3) When the stone is poor in quality then the Sheet Asphalt type of construction should be used.

(4) For heavy trafficked roads even if very good stone is available, it is wiser to use the asphaltic concrete type of construction.

64. The following is a table which gives the quantity of binder. cutback required to coat 1 cub. ft. loose of various aggregates. Where emulsions are used, it is necessary to increase these quantities by 15 to 20 per cent.

Table showing the amount of Cut-Back Asphalt normally required by different aggregates.

Aggregate.	Gauge.	Sp. Gr.	Weight of Bitumen required per c. ft.	Volume of Bitumen required per c. ft.
(1) Metal . . .	1½" to 1"	2·8 to 2·9	2¾ to 3 lbs.	0·046 c. ft. Aver.
(2) „ . . .	About 70% of 1½" to 1" and 30% of ¾" to ½".	2·8 to 2·9	3¼ to 3½ „	0·052 „ „
(3) Sand . . .	About 70% passing 10 mesh screen and 30% passing ¼" screen with very little passing 80 mesh.	2·5 to 2·6	7 to 8 „	0·10 to 0·12 „ „
(4) „ . . .	All passing 10 mesh but with about 15% thereof passing 80 mesh screen.	2·5 to 2·6	8½ to 9 „	0·14 c. ft. Aver.
(5) „ . . .	All passing 10 mesh but with about 30% passing 80 mesh	2·5 to 2·6	11 to 11½ „	0·174 „ „
(6) Filler of Portland cement type.	About 80% passing 200 mesh screen.	2·9 to 3·1	13 to 14 „	0·208 „ „
(7) Filler of the crusher dust type but screened of coarse particles.	All passing 10 mesh but containing about 30 to 40% of 200 mesh. Such fillers are usually deficient in the intermediate meshes.	2·8 to 2·9	11 to 12 „	0·177 „ „

N.B.—Where emulsions are used, the quantities should be increased by 15 to 20%.

65. *Type of binder.*—There are two types of binder that can be used, namely, cut-backs and emulsions; these will be dealt with separately.

66. *Cut-Backs.*—Having selected the type of constructions, Asphaltic Concrete, Asphalt Macadam or Sheet Asphalt the next point to decide is what cut-back should be used; a cut-back with a low solvent content or a cut-back with a high solvent content. One of the main factors in this consideration, although it is one that is often given to great prominence, is the question of the plant to be used for the mixing operation for a high solvent content allows the use of any kind of mixing from graders, oscillating drums, etc., to concrete mixers, while a low solvent content necessitates a proper pug-mill mixer. Before discussing the question of plant, however, it is necessary to explain the effect of the use of a high or low solvent content cut-back on the road.

67. *Low Setting and Quick Setting Cut-Backs.*—The solvent takes an appreciable time to come away from the asphalt, the time taken varying according to the quantity of solvent in the asphalt. Hence a road built with a high solvent cut-back will take much longer to harden than one with a low content and this must have serious consideration—a consideration which far outweighs the question of mixing plant. Apart from the inconvenience to all concerned, engineer and public, from the closing of a road for even one week in order to allow it to set, there is another factor that is of importance. A cut-back road requires to have its final consolidation by the traffic itself, no rolling can give the same consolidation, and therefore with a slow setting road, light pneumatic tyres should be allowed on first, then lorries and finally bullock carts; but it often happens that a road carries almost only bullock carts, or the motor buses

keep to the centre and do not use the haunches; hence such a road never becomes properly consolidated before the bullock carts get on and they promptly cut it to pieces. A good example of this was the experiment with mix-in-place on the Rhotak road in 1933. Mix-in-place with graders had proved successful in Baluchistan where traffic is almost exclusively pneumatic tyred and it was decided to experiment with the method at Delhi to see how it would cope with ordinary Indian conditions. The mix-in-place method with a grader necessitates the use of at least 20 per cent. of solvent and so this percentage had to be used; the result of the experiment was found to be that although the road was closed to traffic for some time and rolled well and did not mark under motor bus traffic, as soon as bullock carts were allowed on, they cut it to ribbons.

68. It may safely be stated, therefore, that for roads which are to carry bullock carts, even if the road can be closed indefinitely and rolling continued for days, it is essential that a low solvent content cut-back should be used which will allow an almost immediate "set". A solvent content of less than 8 per cent. will allow a road to be opened to iron tyred traffic the next day without fear of damage; preferably not more than 8 per cent. should be used.

69. Since almost all roads in India carry bullock carts, experience certainly indicates that it is of the utmost importance that the road should set up sufficiently to take bullock carts within 24 hours of completion. This means that low solvent content cut-backs should only be used despite whatever difficulties their use may entail.

70. *Plant for pre-mix.*—The use of a low solvent cut-back entails a proper mixing unit and it is this question of plant which often assumes such proportions in the eyes of many engineers that they lose all sight of the far greater necessity of a quick set on the road and other important considerations which alone can give the road a long life.

71. Unfortunately, a Pre-mixing plant is too often visualised as a huge unwieldy, very costly contraption: this undoubtedly is due to confusion with the type of plant required for hot-mix.

72. Actually the type of mixture required for low solvent cut-backs is small and can be moved about the road by a few coolies. It merely consists of a 7 cub. ft. capacity mixing box and a power unit—usually of the cold starting diesel type; it can easily be drawn into the side of any road and moved along as the work progresses. The cost is about Rs. 6,000 to 6,500 while running costs amount only to some three or four rupees a day. The gang required for operating it consists of some six men and a mistry and it will turn out from 800 to 1,000 cub ft. of mixed material per day. Compare this with the number of oscillating or revolving drums which would be required for the same output and the horde of coolies required which would congest any road. Apart from these considerations, a mixer ensures far better results, absolutely uniform coating of metal and it practically pays for itself by the saving in asphalt effected for it will coat the metal with a much thinner film than can any revolving drum.

73. That the advantages of the mixer, despite its rather high initial cost are beginning to be appreciated in India, is indicated by the fact that there are now some 30 such machines operating in India.

74. Just as it took time to introduce the steam roller and convince engineers that it was a better proposition, economically and practically

than the hand drawn roller, so it will perhaps take time to appreciate the advantages of the mixing unit over oscillating and revolving drums.

75. It must be fully appreciated that the advantages dependent on the use of a quick set cut-back must under no circumstances be lost sight of by hesitancy or nervousness over the question of plant. The purchase of a proper mixer is the soundest possible investment for it throws open all specifications whereas drum mixers limit the scope of specifications and this will result in wasteful methods.

76. It is recommended that in all pre-mix work with cut-backs, the aim should be to have the road set-up as quickly as possible and that, therefore, a low solvent content cut-back (not more than 8 per cent.) should be used. Proper mixing plant should be employed for the purpose, despite their apparent high initial price, because their use not only ensures an even mix, a thinner film of binder but also a quick set-up on the road.

77. *Emulsions.*—It has already been pointed out that a special stable type of emulsion is required for pre-mix work and that there are certain complications over viscosity where the aggregate consists of coarse and fine particles. hence the use of emulsions for pre-mix is generally limited to the macadam types of construction. However, when a suitable stable emulsion is available and the technique is properly understood, very good results can be obtained with emulsions even in the asphaltic concrete types of construction: the technique, however, is rather difficult and requires very considerable experience, it being impossible to lay down any standard specification and each job requiring to be studied and treated differently. For this reason, and because 15 to 20 per cent. more emulsion is required than in cut-back work, the cost of emulsion pre-mix of the asphaltic concrete variety, can only be considered economic and practical under very special circumstances. From the practical point of view the advantage is that mixing can be carried out in any type of mixer, even by hand: the disadvantages are that water is required and, because of the sloppiness of the mix, considerable segregation takes place.

78. An emulsion pre-mix takes rather longer to set up on the road than a cut-back and great care must be exercised in the rolling otherwise stripping occurs.

79. On the whole, it can be suggested that asphaltic concrete and Sheet asphalt types of construction should not be attempted with emulsions.

80. So far as the macadam types are concerned, the question is rather different for there is not the same difficulty in the technique. The extra cost is still there however and the same care to prevent stripping is required.

81. Probably the fairest criticism that can be made of the practicability of emulsions for pre-mix purposes is the fact that the emulsion manufacturers advocate methods such as the Armourcoat rather than a pre-mix.

82. *Armourcoat.*—Armourcoat is essentially a macadam type of construction but by the process it is possible to build up a rather more dense macadam than is usually laid by macadam pre-mix. In Armourcoat the largest stone is first spread and emulsion applied, the voids in the large stone are then filled as far as is possible by scattering intermediate stone over it and another application of emulsion given; smaller stone is then scattered over and sprayed with emulsion and so on. In other words, layer after layer of stone is spread, each of a smaller gauge than the previous until the final blinding is with sand or fine grit.

83. It will be seen, therefore, that a very dense mat can be built up. The method, however, is expensive as can be seen from Table 1, both from the point of view of the quantity of aggregate required and of the emulsion. It does have the advantage that no plant is required except Sprayers with which to apply the emulsion but, against this it is a slow process for there are so many applications of stone and emulsion and it is essential to allow the road to stand for at least 24 hours half way through the process before proper consolidation takes place.

84. Apart from the above it can be said that the Armourcoat method does provide a macadam type of construction which will compare favourably, from the wearing point of view, with a macadam type of pre-mix.

85. It has already been pointed out that care must be taken with all macadam types of construction to ensure that only the very best quality of stone is used.

86. *Tack Coats or Primers.*—The necessity or otherwise of the use of a tack coat under 1 to 1½″ carpets deserves some consideration here for it is an important point both from the question of extra cost and improved wearing quality.

87. The purpose of the Tack coat or priming coat is to ensure a bond between the base and the carpet but it is very doubtful whether the carpet itself does not itself provide the requisite bond without the assistance of the tack coat.

88. Experience in India has shown that a tack coat is generally unnecessary for 1 to 1½″ carpets either with cut-backs or with emulsions, whether laid on a waterbound base or an old treated surface provided it is roughened somewhat. With emulsions the tack coat certainly is unnecessary because a fair amount of material drains into the base and forms its own tack. Even with cut-backs there is sufficient binder on the stones to provide the bond with the base.

89. It is recommended that tack coats are not required except under one circumstance which will be mentioned, and that all that is necessary is to roughen the base. If the base is waterbound macadam, it should be well brushed but must not be loosened; if an old treated surface it should be roughened by picks, the best method being to make lines of small holes (three knocks with the pick is sufficient for each) running diagonally across the road, 12″ apart and the holes spaced at 12″ intervals.

90. The only circumstance where a Tack or Priming Coat is necessary is when the base consists of new waterbound macadam which has not consolidated well and is rather loose: the purpose of the tack in this case is not to ensure the bond but to hold and consolidate the macadam surface together. For this purpose the tack or primer should consist of a material, such as a 40/60 mixture of Fuel Oil and Asphalt, which will sink well into the base and bond it.

91. One objection to a tack coat is that, unless it is applied very very thinly, there is a danger of it cutting into and enriching the carpet making it too fat in asphalt and so causing subsequent waving.

92. *Re-Sectioning.*—A 1 inch to 1½″ carpet will cope with most inequalities on a road for it can be laid from ¾″ to 2″ in thickness but it should never be laid more nor less than these limits. The reason for this is that if laid thinner there is a danger of one stone having to carry the full load

or, if greater then stones will lie three or four deep and there will be no interlock. Hence if there are any inequalities over 2" in depth, it is necessary to lay the carpet in two layers, the bottom layer to consist of coated stone only and containing no smaller fragments of stone. For the bottom course it is quite sufficient to use only 2½ to 3 lbs. of binder per cub. ft. instead of the usual 3 1/3rd lbs. This base course should be spread and well rolled before the top course is spread.

93. Another objection to laying too great a depth of the carpet is that consolidation will be uneven and where it is much thicker than in other places, a low spot will develop.

94. *Lateral Supports.*—Lateral Supports should always be provided for any carpet over ¾" in thickness otherwise, especially with the bullock carts using the haunches of the road, the carpet will gradually be pushed out.

95. The best form of lateral support is a kerbing of boulders, bricks or cement concrete whichever will prove cheapest. Since a roller, when consolidating the carpet, may damage the kerbs it is always advisable to put the kerbing in after the carpet is consolidated; wooden baulks of timber held by spikes can be used at the time of spreading and rolling. These are removed and the kerbing put in.

96. An alternative to kerbing, though not nearly so satisfactory, is to excavate a trench 12" wide by 2" deep along the edges of the road and fill the mixture into the trench; this is known as "tucking in" and is quite effective provided the macadam base extends beyond the edge of the carpet.

97. *Conclusions and recommendations.*—The following is a summary of the conclusions and recommendations that can be drawn from this paper.

Methods which should be discontinued.—1. Two Coat Surface Dressing.

2. Grouting and Penetration Methods. Both these methods require an excessive quantity of binder which is both extravagant and detrimental.

Types of construction for Indian conditions.

For Light Pneumatic Tyred Traffic }
Light Bullock Cart Traffic } Single Coat Surface Dressing

Medium Heavy Mixed Traffic.—1 to 1½" carpets.

Heavy Bullock Traffic.—2 to 2½" carpets.

Types of Carpets.—These should be of pre-mixed construction or of a method such as Armourcoat which provides both density and a pre-coating effect.

Carpets are of three main types:—

(1) Asphaltic Concrete—*i.e.*—A mixture of Stone and Sand.

(2) Asphaltic Macadam—*i.e.*—A graded Stone Carpet.

(3) Sheet Asphalt—*i.e.*—A carpet in which the Sand carries the wear of traffic.

These may be laid in thickness of from 1 to 2½″ according to traffic requirements. The thicker the carpet the larger should be the size of the stone. The large stone should be not more nor less than 2/3rds of the thickness of the consolidated carpet.

Comparative Merits of the three types.

1. *Asphaltic Concrete* provides the densest and strongest construction.
2. *Asphaltic Macadam* is excellent but depends for success to a very great extent on the metal. Unless the metal is of the very best quality, it is wiser to use the Asphaltic concrete type.
3. *Sheet Asphalt* gives a close fine surface without requiring polishing by traffic. Sheet asphalt is not as strong as the other types because the sand carries the wear and inherent stability is dependent on the binder and the internal friction of the sand particles and not on the interlocking of the stone fragments.

Sheet Asphalt, however, is of particular value in cases where the available stone is of poor quality and in such cases should be used in preference to the macadam type.

Binders to be used.—Either cut-backs or emulsions may be used for these carpets.

Cut-backs.—It is most advisable that the road should "set-up" quickly and allow traffic to use it 24 hours after laying. The solvent content should not, therefore, fall above 8 per cent.

Plant for Cut-back Pre-mixes.—Despite its apparent high initial cost of Rs. 6,000 to Rs. 6,500 it is essential that a pug-mill type of mixer should be used for such a plant alone allows any type of mix to be made, ensures a thin film and so saves in bitumen, permits the use of a low solvent content cut-back and so a quick-set road. Such a plant will justify its purchase immediately.

Emulsions.—The dipping process is not sound either in practice or theoretically for, although it is a means of pre-coating the aggregate, there is no means of ensuring a uniform coating nor of preventing an excess of binder; both these are the faults of the grouting or penetration method.

Special stable emulsions should be used for pre-mix work and it is possible, though rather difficult for the inexperienced, to make the asphaltic concrete types of construction. The use of emulsions for pre-mixing entails rather higher costs as more emulsion has to be used than cut-back. General usage is to advocate the Armourcoat type of construction in preference to pre-mixing. The Armourcoat method comes within the macadam type of construction and necessitates the employment of the best quality stone only.

Tack Coats.—These are unnecessary for 1 to 2½″ carpets except where the base is loose. The base should always be roughened but not loosened in the roughening operation. Where the base is loose, it should be primed with an asphalt/fuel oil mixture to bind the base together.

Lateral Supports.—These should always be provided, preferably in the form of kerbing but if funds do not permit this then the edges of the carpet should be tacked in.

98. *Recommendations for road specifications.*—Surface Dressing is suitable only for light trafficked roads and there is nothing further to add on the subject for it is a method with which most people are very well acquainted.

99. The Specification which will be of the greatest utility in India is undoubtedly the 1 to $1\frac{1}{2}''$ carpet made of pre-coated aggregate for it allows sufficient variation in thickness to cope with most inequalities and yet, even in those places where there is a greater or less thickness of mat there is a uniform coating of binder which cannot be obtained by any method where the binder is applied after the aggregate is in position on the road.

100. The asphaltic concrete type using two parts of stone to one of sand is the most satisfactory and strongest. The macadam type should only be used where the stone is of the very best quality and, then, it is preferable to give it a liquid seal rather than a mixed chipping seal. The Sheet Asphalt type of construction is of particular value where the quality of the stone is very poor for the sand. not the stone, carries the traffic.

101. Let us hope that in a few years time from now every Road Authority in India will own its own proper mixing plants—just as they do steam rollers—and that the laying of pre-mixed carpets will become a matter of routine rather than a rather bold experiment as it is treated to-day. That pre-mixed carpets are the solution of India's road problem is unquestionable and, therefore, the sooner more extensive works are carried out with them in every part of India the better.

Mr. G. G. C. Adami (the Author): Mr. Chairman and gentlemen: I do not think that I have very much further to add to this paper. It is such an enormous subject that it has already been sufficiently difficult to confine it within reasonable limits. I have been asked by one or two delegates exactly what I mean by two coat surface dressing. This is where the second coat is applied immediately after the first. I have omitted to refer to kankar or laterite roads as bases for asphalt carpets. It has been found that these make excellent bases for such carpets and any of the types of construction referred to in my paper may safely be laid on them. The only precaution that requires to be taken is that a priming or tack coat should be applied before laying the mat. The best type of material for this purpose has proved, in my opinion, to be a 50/50 Fuel oil asphalt mixture applied at one-quarter gallon per square yard (30 lbs. per sq. ft.) for this penetrates better into kanker or laterite than into other materials.

DISCUSSION ON PAPERS NOS. 2, 5(*a*), 5(*b*) AND 6.

Chairman: Gentlemen, I hope that many people will come forward and criticise these papers. But before they do so, there is one thing which I would like to say. I think the four papers which we have now under discussion definitely emphasise the necessity for us to get down to some standard form of measurements. I see, for instance, one paper refers to gallons per square yard and annas per square foot. Another paper deals with tons per mile and rupees per 100 sq. feet; and so on. I think you will all agree that it is most confusing. There is one thing that I do hope will emanate from this Congress and that is that we will get all Governments to agree, before we next meet, that whatever papers are written will all conform to some standard form of nomenclature. Of course, this point has been mentioned on a previous occasion and I am all for abolishing the gallons and square yards and dealing only in pounds and square feet.

Mr. K. G. Mitchell: Supplementing what fell just now from Mr. Macfarlane, I would like to suggest that we should do away with the gallon and take to pounds and hundredweights. You buy most of these materials by weight and you deal with them in hundred sq. ft and it must be an unnecessary complication to have to convert gallons for the purpose of estimating into pounds and tons. I think personally that pounds or hundredweights—preferably pounds—are preferable to gallons.

Mr. B. F. Taylor: There is one point on which Mr. Adami will, I hope, be able to help us in Assam and that is the strange antagonism that certain types of metal seem to have for bitumen. In Assam where we have rain for 9 months and dry weather for only three, hot applications are extremely difficult as it is very rare that we can get a road sufficiently dry to give them a fair chance. We have therefore been driven to cold emulsions which looked quite hopeful until recently but I regret to say that in many parts of the province they are breaking down deplorably. In the course of our investigation to find out the reason it seems to boil down to this: that to certain types of our metal bitumen will not stick. Some is of the quartz groups and some of a kind I cannot classify geologically but it has a weathered or fungus grown surface which has been found to be utterly useless for bitumen. We have tried to get some explanation and we have

been investigating this point but we have not yet got any satisfactory answer at all. It is quite impossible for us to select our metal. Our transport cost is enormous and we have got to use what is nearest or on the spot. Perhaps this point has already been investigated by Mr. Adami and others and if they will tell us if there is any way of overcoming it or what the reason of it is, we should be extremely grateful to them.

Mr. O. H. Teulon: Mr. Chairman and gentlemen, I should like first of all to apologise to Mr. Stubbs for having misunderstood the specification for water premix tar. I am sorry I made the mistake, but we have not tried it in Burma at all and I made the mistake through ignorance. In paragraph 7 of Mr. Hunter's paper (Paper No. 2) the question of the life of the surface of the road itself is mentioned. Now when we are considering this matter of road loans, it seems to me essential that we should if possible determine what the lives of these various surfaces are in respect to the traffic they carry. For financial reasons the P. W. D. Code divides residential buildings into certain classes and if we could divide roads surfaces up into similar classes, it would help very considerably in determining the financial effects of any loan. I should be very glad if Mr. Hunter could give us further information on this matter from his experience. The suggestion I should like to make is that we might assume that certain surfaces, provided they are properly laid and properly maintained, will carry certain intensities of traffic indefinitely and when the intensity of the traffic increases, it becomes necessary to resort to reconstruction. If this assumption can be accepted, it will help very much in submitting proposals for accepting loans as we will be able to fix arbitrarily the life of any surface.

Mr. G. A. M. Brown: Mr. Chairman and Gentlemen, there are two points in Mr. Adami's valuable paper (Paper No. 6) to which I wish to refer. The first is in connection with his remarks regarding the function of the stone, paras. 4 to 7.

I think we are perhaps inclined to forget that it is the stone which carries the traffic and that when we discuss the failure of surface dressings we are apt to blame the dressing when very often we should blame the stone base.

The reason why the surface painted N.-W. Frontier roads stand up to heavy bullock cart traffic, is, I think, largely due to the excellent quality of their stone and to the manner in which it is consolidated. We have found from experience that a single road roller cannot consolidate, properly, more than 600 cft. to 800 cft. of metal per day when the minimum amount of stone dust and clay binder is used. If more than the minimum amount of clay in the binder is used, in the water bound work, it is possible considerably to increase the daily rate of consolidation. The daily rate of consolidation is therefore to some extent an index of the quality of the consolidation.

With regard to Mr. Adami's remarks on the scope of single coat surface dressing, para. 16 of his paper, most of the roads in the Frontier to the south of the Kohat Pass, are surfaced with Colas and seldom require repainting more than once in three years. The traffic on these roads consists largely of lorries with only a small percentage of bullock carts. The same surface treatment was found to be unsuccessful north of the

Kobat Pass where there is a large percentage of heavy bullock cart traffic. On these northern roads surface dressing with tar has been found to withstand an intensity of mixed traffic of 200 tons per yard width per day. These roads require repainting with tar every two to three years.

In some sections an intensity of 350 tons per yard width per day has been carried without failure.

The Attock-Peshawar road over which the Congress toured is an example of a tar painted road which carries heavy bullock cart traffic. The bullock carts on this road are of the two wheeled type with a 3 inch width iron tyre. The tyre is usually convex outwards and I imagine that the actual width in contact with the road is not more than an inch. A heavily laden Peshawar bullock cart weighs as much as 2½ tons. By comparison, the bullock carts in Delhi are of the four wheeled type and as we saw at the weighing machine the other day, a laden cart weighs only one ton.

Mr. Dean told us that surface painted roads in Delhi would not withstand an intensity of traffic of more than 200 tons per yard width per day and that if there was much bullock cart traffic this figure should be divided by four.

It seems clear from this that we cannot lay down any general limit for the intensity of traffic that surface painted roads will carry. It varies too much in different Provinces.

Our experience on the Frontier, however, shows that under similar climatic conditions and given good stone and first class water bound consolidation, surface painting with tar can withstand successfully loads which in other provinces require pre-mix carpets.

The reason why tar surfacing on our northern roads has proved more successful than surfacing with a cold bitumen emulsion is that the initial coat of tar penetrates better.

If the water bound consolidation is done properly and an excess of clay binder has not been used, the initial coat of tar will penetrate at least half an inch. If failure occurs, the extent of the penetration often indicates the reason for the failure. For example, if the tar has not penetrated by more than ¼ inch the fault is either excess of clay in the water bound binder or overheating of the tar. The latter fault can be detected at once by inspection.

If the tar has penetrated by more than ¼ inch the reason for failure is faulty consolidation.

The second point in Mr. Adami's paper to which I wish to refer is in connection with para. 52 of his paper. The latter part of this para. is more or less the policy we follow in the Frontier where our funds are strictly limited.

Old water bound roads are remade and surface dressed with two coats of tar, tar being used because of its excellent penetrative property. If the road wears out before two years, it indicates that the penetration is insufficient to prevent the interlocked metal below from being disintegrated.

The road is then surfaced with a carpet of such a thickness as will prevent this disintegration. The carpet, in effect, increases the penetration by the same amount as its thickness.

This is probably the cheapest way in which we can develop our roads, namely, first to treat the remade water bound surface with a dressing having a reasonably good penetration and to follow that up with a carpet as and when the latter is found to be necessary.

As Mr. Adami says in his paper, when the initial surface dressing has worn out it will afford an excellent base for the carpet.

Mr. G. Reid Shaw: Mr. Chairman and gentlemen, I should like first to congratulate the Chairman on his sense of humour to having both Mr. Adami's and Mr. Stubbs' papers criticised at the same time. Mr. Stubbs will tell you that tar surfacing is the best thing in the world while Mr. Adami will say that all surfacing is nonsense. In many of these papers surface painting work has been criticised and there is talk of losing the salvage value of the old road, I do not think any Engineer would start this kind of work haphazardly and say that he is going to pick up this or that road so as to surface paint it. He has got a programme of work ahead of him and painting follows as a natural sequence to metal re-surfacing, and there is therefore no loss of salvage value of the old road surface when surfacing is undertaken. The operations follow as a natural sequence in the ordinary course of annual maintenance.

There is just one point in which I do not agree with Mr. Stubbs. He has had far more experience in the matter than I have and it is possible that he is right and I am wrong. That is the amount of tar that he uses in his first coat. I think the first coat of surface painting needs to be a richer coat, considerably richer, than what he uses so as to get penetration. Certainly in a wet climate like ours (in Assam), the first coat penetration is of enormous importance. Many writers have discussed how the bullock cart traffic ruins surface painted roads. We all agree with them that in the case of very heavy bullock cart traffic no surface painting will stand. This is particularly so in places where the bullock carts are stopping and starting like railway station approaches. Straight bullock cart traffic along the road does not do so much harm as when the bullock carts keep starting and stopping and moving about at the same place. That is what happens near villages. In certain parts of Assam we find stones which have a natural aversion to binding with bitumen. One is a whinstone and it is probably one of the best stones we have got in the whole of Assam, but in the quarry from which it comes there is a weathered looking formation which is not confined only to the exposed surface of the stone. It comes in large veins in the quarry and nearly every bit of the stone that comes out has got one side with this brown weather looking surface on which bitumen will not stay for a second, in fact it runs off as fast as it goes on. If Mr. Adami could give any explanation or could devise any method by which we can overcome this, we will be delighted.

Another point on which Mr. Adami condemns surface painting is that the amount of bitumen is excessive for the amount of chipping used. I do not think that the whole idea of surface painting a road is the amount of chippings which you can stick on to bitumen. The first idea of bitumen or tar surfacing is to get a weather proof road. After that the greater the amount of chips that can be fixed down as a wearing coat the better.

Mr. D. Daniel: Mr. Chairman and gentlemen, I think paper No. 1(A) should have been brought up to-day for discussion along with these papers. Anyhow that paper has been separately discussed, but I wish to point out that some of my remarks would equally apply to that paper also.

As regards paper No. 2 and papers Nos. 5(*a*) and (*b*) these three papers may be broadly divided into two classes, the one attempts to arrive at the economic aspects of the various wearing surfaces and the other attempts to describe how tar can be used to reduce the maintenance cost. On papers like these, I should have thought that discussions on the broader issues involved would be more profitable than dwelling on the details of a number of specifications. At the outset I should therefore remark that tar and tar compounds wherever used have been gradually given up in favour of the more suitable asphalt which all of you are aware of. Painting the surface annually for miles and miles together is a very tedious task and this also finally works out into a very bad mat and inconveniences traffic as was pointed out by Mr. Dean yesterday. This finally helps to distort the metal below under very heavy country cart traffic. This is our experience in the Madras roads.

After reading papers 5(*a*) and (*b*) one is left with the impression that in the Punjab out of sheer necessity tar is being used to minimise the maintenance bills owing to its cheapness in the initial cost. That province seems to be undergoing the same phase which the several corporations in the early days were undergoing. They have all now gone for more durable materials for their heavily trafficked roads. Mr. Coats, the late Engineer to Madras and Calcutta Corporations, who had large experience in the use of tars had written to me in 1929 that "with the introduction of bitumen compounds tar should not be used unless it can be got so cheaply as to justify its use." This seems to be the reasonable attitude that one can take up regarding the use of tar. Except its initial cost, tar has no special qualities in its favour. (Laughter.) In paper No. 5(*b*) failures of tar in the past are attributed to improperly dehydrated tar or want of a filler and an example of success with tar quoted is the Mall at Lahore laid in 1916. But tar used then could not be the modern tar. Its success should, therefore, be due to something else which requires further investigation. Further, because the macadam below has not been reformed from 1916 cannot be a criterion of its success. What kind of serviceability the surface has rendered to the public should be looked into. I mean whether the surface was wavy or undulating and consequently inconveniencing the public. Or at least what kind of maintenance it has udergone and other traffic factors have to be examined. Since writing these notes, thanks to Mr. Mitchell's forethought and genius for organisation, I had the opportunity, as all of you had, to see the Mall and all the other tarred roads we were shown. The surface of the Mall is very good. I see it is due chiefly to the pohibirion of country cart traffic. Also in the main roads bajri is used for blindage. These are very hard waterworn crystalline nodules more or less like iron pieces. This forms a very good mat and all over the Punjab they seem to get such kind of material. The rainfall also is very light and does not wash away the light oils or free carbon. The country carts have not also iron tyres for the most part. The best granite metal in the Madras Presidency when tested is found to have a French Co-efficient of wear of 17 and 5 in the dry and wet test respectively, while the metal in Jhandawala quarry

in Delhi is reported to have twice its strength. I am therefore very sceptic about the permanent advantages of using tar in Madras where there are several factors contributing towards failure. I am glad to see Diwan Bahadur Ayyangar of Mysore has been converted to some extent yesterday and I shall wait for the results of his experiments. Mr. Trevor Jones' conclusions in paragraph 24 of his paper give us an insight into the future requirements of the Punjab roads. He feels that more permanent construction will be necessary and ends with the statement that the construction of the concrete roads appears to be the solution, with the latter of which I do not quite agree.

If the papers 5(*a*) and (*b*) are interesting in the methods adopted to solve the immediate maintenance troubles which is common to many provinces, paper No. 2 is very instructive in the way in which the economic aspects of the various wearing surfaces are worked out. This paper is very important from the point of view of the Government of India and the Provincial Governments, which are on the eve of embarking on a comprehensive plan of road development from loan funds as a result of the repeated and able representation by Messrs. Miller and Ormerod and the energetic Secretary Lieutenant-Colonel Smith of the Indian Roads and Transport Development Association. Selection of bridges and new roads to be constructed from loan funds offer no difficulty, but it is the selection of the type of modern wearing surfaces suited to any one road that is going to be one of the difficult tasks of those in charge of roads. The percentage of such roads requiring modern surfaces may be small in each province and yet the type has to be settled on a rational basis before any loan is given. Paper No. (2) has outlined some methods adopted by the Chief Engineer of the United Provinces and should prove very useful in a general manner. But, unfortunately, there seems to be no reliable and accurate data readily available in other provinces. If the results of the various experiments are to be useful in such a vast country like India, information regarding the height above mean sea level, the total rainfall, maximum and minimum temperatures, nature of subsoil, the thickness and nature of the hard crust available as foundation, the volume, character and distribution of traffic, in other words, the number of vehicles, the proportion of traffic to steel tyred ones, and whether the latter is distributed all over or only in tracks; and lastly, the width of the road which gives the intensity of traffic for which the cross section is designed have all to be given for each and every experiment. Also to state that bitumen was a failure and so on, using a generic term gives only a vague idea about these experiments. Bitumen according to the 1929 definition of the British Standard Engineering Association includes all kinds of asphalts with penetration from 5 to 300 and tar with specific viscosity from 3 to 100. So are we to understand that all bitumen in the market is a failure? We have therefore to be specific in our description of the materials used. This will be of use to both parties who deal in and use the various materials. In fact some firms really want to know the defects in their materials with a view to rectify them or suggest improvements in their specifications or point out the mistakes, if any, in application. If we are not going to be open-minded in this respect. I should think that the usefulness of our experiments will be lost. When asphalt is said not to adhere to the stones in the Punjab, one wonders why the experience there differs from that in other parts. Probably, the qualities of stone, if it had been

tested, and the climatic conditions would have explained this different experience. If the aggregate is soft limestone, dust is likely to be formed under traffic between the asphalt paint and the stones, whereas tar has got better affinity to lime stones. However, things like these have to be guessed. Also the qualities of the metal used should be tested for compression for attrition and for abrasion and should be recorded. I understand that these three papers were originally intended for the International Road Congress and hence, I believe, some such details have been omitted. I only wish to stress the necessity for the introduction of a standard form for recording the details of the various experiments to be done in future which will help us in the selection of suitable wearing surfaces, embodying all this information for each and every experiment just as the Concrete Association have done it for their pavements all over India.

After reading all the papers one cannot understand what we are actually aiming at. There is a medley of specifications, some even of unscientific nature as pointed out yesterday by one gentleman, such as mixing tar with mud, etc. We have to divide our experiments in future broadly into two, *viz.*, one for capital works and another for devising cheap ways of maintenance of roads. Experiments for capital works should be confined to standard works, such as concrete, sheet asphalt, asphaltic concrete, asphalt macadam and painting. Materials to be used should be fairly standard ones and if possible should be subject to laboratory tests. They have to be laid on important typical provincial roads with a special staff and watched.

It will also be better to record their annual maintenance costs in terms of unit of road unit of traffic; in other words the annual cost per mile of foot width per ton of traffic per foot width. The United Provinces seems to be doing this already. This will also help us a good deal in working out the economic aspect of the various wearing surfaces in a more rational manner than we are able to do at present. I am sure the genius of Mr. Mitchell whose time and energy were taken up till now by the Government of India for other urgent purposes will, before long, tackle this problem also.

As I have observed already, I have dwelt only on the broader aspects, involved in the subject matter of the three papers, which are more important and I shall leave the details alone. By this I do not belittle the information given in the papers concerned. Everyone knows what it is merely to execute and what it is to write papers. Nothing but praise is due to the authors of all these papers and particularly to Messrs. Dean and Hunter, who have taken immense pains to describe in detail all the works they have done. I also request that Mr. Dean gives his special attention to the works on the roads carrying heavy country cart traffic and gives us the result of his experiments which will be of immense use to Engineers who have to deal with provincial roads with heavy mixed traffic.

As regards paper No. 6, Mr. Adami's paper is a faithful and a true record of the results of the works done by Messrs. Burmah Shell Company. It is a very valuable paper and there is not even the slightest taint of the firm's interests. I really congratulate the author of the paper and Messrs. The Burmah Shell Company on its excellence. The Engineer's chief trouble, as Diwan Bahadur Ayyangar pointed out

yesterday, is to find out the best pavement that will serve the dual purpose roads. Mr. Adami's paper has eliminated practically all asphalt pavements for heavy bullock traffic except Shelcrete. We have done it in the Madras Presidency in some places and so far they are successful. There are one or two pavements standing for the last about six months without the slightest rut. Still it has to be tested a little longer and then conclusions have to be arrived at. (Applause.)

Colonel G. E. Sopwith: Mr. Chairman and gentlemen, suffering as I am from shell shock from the recent bombardment, I only propose to say one thing. Mr. Daniel said that he felt that the Mall at Lahore required some more investigation as it was impossible that the tar used there could be the same as used to-day. The company to which I belong distilled modern tars in those days. The stills were first started in 1915 and the Mall at Lahore was treated with the same Shalimar tar as the roads in the Punjab are treated with to-day. (Applause.)

Mr. R. W. Parkhurst: Mr. Chairman and gentlemen, I should like to express my personal pleasure at having had the opportunity of reading these papers and I think the authors are to be very heartily congratulated on the wealth of material they have furnished and the manner in which they have set it forth. As was mentioned a few moments ago—it is a very good idea to group these papers together for discussion for this reason, that they emphasise a very interesting point in connection with road development—that is the underlying principle of stage construction. I think that the light roads that we have had the opportunity of seeing in the Punjab will no doubt later on be surfaced with heavy material when and as traffic requires it. We have seen other roads in the vicinity of Delhi which are in practice of greater thickness and are possibly fitted to carry heavier traffic. The point that I make is that if the roads are built with this idea of stage construction in mind they may be used as foundations for successively higher types of surface as traffic requires them. With regard to Mr. Hunter's paper, I may say that to my mind his method of analysing the cost and comparing the different types of surfaces are perfectly logical, but as the author implies, a reservation must be made in applying these principles. Variations in traffic may bring about certain modification and as a matter of fact might entirely upset the calculations. Speaking further with regard to paper No. 2, as to the earlier work with bitumen, I should like to ask the author whether detailed specifications are available. If so, it is possibly to be regretted that these could not have been included in the paper to afford a comparison with specifications for more recent work which are given in detail. Apparently, there was a great deal of difficulty with this earlier work and in connection with the reported unsatisfactory results of some of these projects in the United Provinces, two observations, it appears to me, may be made—

(1) The quantity of bitumen has a very direct relationship to the success of any bituminous work.

(2) Satisfactory results are secured only when proper selection of type is made and the specifications are accurately followed.

Concerning the first point the statement is made that the road surfaces, whether asphaltic concrete, grout or sealcoat, became soft under heat. It is well known that any bituminous material irrespective

of origin and whether tar, residual or natural bitumen, softens under heat, the degree of softening depending upon the quantity used, the consistency, whether loaded with fine mineral matter or not, etc. If too much bitumen were employed in the cases referred to, it would indeed be surprising if the surfaces did not soften and move under concentrated traffic in hot weather. It is suggested that a reduction in the quantity of bitumen used in this earlier work, which however, was constructed according to the best knowledge and experience then available, would have produced more satisfactory results.

The author implies that the difference in results achieved with natural and residual bitumens is due to some differences in their composition. This is hardly the occasion and in any case time does not permit detailed comment along this line, but whatever these differences may be, I think it will be fairly obvious that method of employment of any material will be at least of as much importance as its nature.

With regard to the second factor, the author states that grouted work becomes rutted under bullock cart traffic. Although I speak with some diffidence on this point, I am under the impression that a complete solution of the problem of how best to carry the bullock cart has not yet been found after some 15 years' experience with bituminous roads in India although as the recent tour has revealed, much progress has been made. Asphaltic mixtures capable of withstanding such traffic when laid over proper foundations have been produced, but at a cost prohibitive in so far as provincial roads are concerned at present. Satisfactory grouted roads have also been produced, examples of which, amongst others, were included in our inspection tour on Monday. Mention is made of this to indicate that until the limitations of the various types of bituminous wearing surfaces are more clearly defined, it would be well to select types whose performance has been thoroughly tested. The experimental work, report on much of which is being made at this Congress, will go far to establishing what these limitations actually are.

With regard to paper No. 6, Mr Adami seems to consider that grouted macadam is not altogether suited to conditions here. I may say that India to my mind is a very large country where conditions vary very much. You have different climatic conditions in the North than in the South; Assam is not the same as Bombay, and it is very difficult to state that any particular type of work may not be satisfactory under certain conditions. It seems to me that although grouted macadam is not altogether a scientific process, still if it is carefully followed it gives good results. I think the engineer really is the person who must select from all the various types of construction at his disposal the particular kind of surface which is suited to the conditions under which he has to work. I think that is all I have to say. I appreciate very much being given this opportunity of speaking. (Applause.)

Mr. N. V. Modak: Some fundamental changes in the mode of construction of district roads have been recommended for consideration. These changes mark a distinct departure from the current practice, and require to be carefully examined before their adoption.

The main idea is to provide uniform and only necessary coating of the binder to the aggregate, before consolidating it on the road surface. This is proposed to be done by the introduction of *cutback* asphalt and cold premix by portable plant. Further, it is proposed to adopt (1) asphaltic concrete using large proportion of big size metal, (2) shell-macadam with seal coat, (3) stone-filled sand sheet asphalt.

Cutback asphalt is specially prepared by the addition of a certain small proportion of light gasoline or kerosene to ordinary straight run asphalt, in order to bring it to a suitable form to coat cold aggregate with hot asphalt. Addition of solvent only reduces the softening point from 325° to about 200°F., and makes it more fluid. Uniform and thin coating can be better secured if there be as little a difference in temperature as possible between the stone and the binder. Cutback asphalt reduces this difference, but still leaves a considerable margin. No doubt, increased fluidity also helps, but it is doubtful how far the coating is uniform. Further, with the increased surfaces to be coated in case of fine aggregate, the difficulty increases, and after the evaporation of the volatile portion the binder film is left weaker.

Cold-mix plant simply premixes the aggregate and the binder in volume proportions, whereas in the hot-mix, there is a correct weighing and proportioning of the constituents. All sizes of plants, including semi-portable ones are available for hot premix work, and if the quantity of work in certain radius is sufficient, the larger initial cost of the equipment may be justified. Somewhat higher working cost would be more than counterbalanced by the quality of work done. Finest aggregate or the filler can be used to fill in the voids in order to make the surface dense and stable. This would help to increase the life of the surface, and reduce thereby the maintenance charges. It may be mentioned that life of these types of roads, even with intense city traffic, has been found to be 12 to 15 years with practically no maintenance for the first five years, and about As. 2 per sq. yd. per annum thereafter.

As regards the types of construction, the asphaltic concrete using large proportion of big size metal, and sand with bitumen just sufficient to fill in the voids was tried with hot-mix method in Bombay sometime back. For a 3 inches carpet, metal used was 1¼ inches to 1 inch in size and the percentages of metal and sand were 58·2 and 31·4 respectively by weight. Bitumen added was 6·0 per cent. A thin hot plant-mixed seal coat was also provided wherever necessary. But the surface did not come up to expectations, and the potholes began to appear in about 2 years' time, and a wearing carpet had to be laid on it.

Probable reasons for failure seem to be segregation and voids in the surface. On account of the segregation, it is possible the spaces between the stones were not uniformly filled in by sand It therefore seems doubtful, if the theoretical assumption of filling in all the voids in the stones by sand adhering to stone is fulfilled. While mixing, on account of the abrasive action of the different particles of the aggregate, sand is not likely to stick to stone to such an extent as to fill in the voids. Further the voids in the sand amount to usually 30 to 35 per cent. and the space occupied by bitumen coating the sand would be about 15 per cent., leaving about 15 to 20 per cent. voids. This type of surface would therefore necessarily require occasional sealing.

With graded stone, and a larger proportion of finer aggregate, about twice the amount of stone, with sufficient quantity of filler to fill in the voids in sand, and a properly designed concrete mixture, there are fewer chances of segregation, and it has given satisfactory results, when laid under ordinary conditions of traffic, etc. No doubt this type of mixture has also failed, but it is under quite different circumstances, when laid on the slope of the approaches of a bridge under very heavy bullock cart and motor lorry traffic.

Trial stretches of premix Shelmacadam with premix seal coat by cold mix method have been laid in continuation of semi-grouting work for the same road, under the same conditions of traffic for the purposes of comparison. Cost of premix work was higher than that of the semi-grouting. Surfaces were examined after about a year and a half. Semi-grouted surface appeared rich and in perfect condition. Shelmacadam surface appeared dry, as if there was no binder, and the seal coat had worn out in some places, and required renewal if the surface is to be saved. It appears on account of richness of asphalt in the top surface of the semi-grouted road, it formed an effective water-tight seal by admixture with grit and dust spread on it in the final coat. Richness of asphalt thus serves an important purpose in this case. No doubt the extra asphalt in the lower portion serves the purpose of partly filling in the voids, and does no useful service.

In sand sheet asphalt, as already stated, considerable amount of voids in sand remain unfilled. Unless these are filled up by filler, or the surface sealed with liquid seal, it is bound to wear earlier. Filler required for this type of mixture per 100 square feet will be only about a cubic foot. This combined with a properly graded sand and proportionately a bit larger amount of asphalt will give a considerably better and permanent surface. Cost would no doubt be somewhat higher but the additional life and reduction in maintenance charges would more than repay it.

Two coat surface dressing holds its own, where new water bound surface is to be treated, and there is intense automobile traffic mixed with light bullock cart traffic. ½ inch carpet formed by two coat method serves as an effective cushion and makes up for slight irregularities in the surface. For city streets there is a further advantage. Second coat is usually covered over by a mixture of ⅛ inch grit and dust and seals up the whole surface forming smooth surface, very suitable for cleaning. (Applause.)

Mr. R. G. Burt: Mr. Chairman and gentlemen, the remarks I have to offer apply not only to the four papers that are under consideration now but also to a previous paper. In all these papers the material has been almost invariably described under its trade name which tends to confuse the issue. It is going to be difficult enough to correlate the results of the experiments carried out in various parts of the country under varying conditions and also under various specifications for laying the road without this further complication of not knowing the exact nature of the material used. I think that this is a position from which we should get away as soon as possible and would suggest that one of the tasks which lie in front of this Congress is the classification and the evolving of specifications for the actual material used. The firms which produce and sell road materials might consider that this is not in their interest, but it has proved to be not so in the case of other industries. The classification and standardisation and the production of material to specifications is ultimately in the interests of both the producer and the user. I would also like to suggest that any further experiments which are undertaken in the future should very largely concentrate on the using of material which is indigenous or manufactured in this country, rather than on material which may be imported. This, I think you will agree, is also in the interests of the country.

Chairman: Gentlemen, I am quite sure we are all very grateful to the various speakers who have given us this interesting discussion and I have very little to add myself. I noticed that during the very interesting and somewhat destructive speech of Mr. Daniel, Colonel Sopwith was pawing the ground with impatient hoof and I am quite sure that when he made his reply he was surprised by his own moderation. But speaking as a representative of a province that perhaps uses tar painting more than any other province in India, there is one thing I would like to say. Reference was made to the inconvenience caused by repeated resurfacing. I would like to say that repainting is a thing which causes practically no inconvenience at all. We do not close the road at night; we simply do the work in short stretches, and at the end of the day's work after the road has been provided with grit and well rolled, it is immediately opened to traffic. In the case of the Mall in Lahore, we simply put a row of tar barrels down in the centre and divert the traffic to one side while we tar paint the other. The whole Mall was done in September just before the Local Government moved down from Simla and the inconvenience caused was almost negligible.

I do not think I have anything more to add and I will now call upon Mr. Hunter to reply to the criticisms on his paper.

Mr. C. F. Hunter (the author of Paper No. 2). I do not think I have very much to reply to but I was asked one or two questions. One was whether I could give any idea as to the traffic up to which the road surfaces would stand. I am afraid I could hardly do that. But I have discovered one thing. Going through our records of all our miles I have found that miles carrying over 80 to 100 tons of bullock cart traffic per foot with per 24 hours give trouble in maintenance. Mr. Adami in his paper has stated that if a painted mile would not last for two years you should use something better. So I again went through the records of the miles which lasted two years and I find that they practically agree with my own conclusions, *i.e.*, that they carry about 100 tons of bullock cart traffic per foot width. So that as far as I can see, it is not safe to rely upon bitumen painted surfaces, at any rate, such as we have in the United Provinces, to stand more than that without showing certain signs of distress and giving a certain amount of trouble in upkeep. I was also asked if I could give a little more information on the economics of the various treatments. I am afraid I cannot give you that here. That work was done quite a long time ago, and incidentally of course the would-be lives of stone miles are decreasing very rapidly. Those figures we got out about three or four years ago. Motor traffic has increased very much since then and the probability is that these economic lives will become shorter.

I was also asked if I could give some information as to the quantity of bitumen used in the pre-mix and grouted work. I can supply that but I have not got it here. Pre-mix, *i.e.*, hot pre-mix not such as we saw the other day, was done by a large firm of contractors and it was done to their specification. I think they would be the first to admit that they did use an excess of bitumen in the mixture. As regards our own work, *i.e.*, grouted work, that is done departmentally. There again I think we can agree that we used too much bitumen. It is rather difficult to control or to make a good grouted road with very much less than we used and I think it is one of Mr. Adami's contentions that it is rather a wasteful process. With that I agree. I think those are all the points raised.

Mr. S. G. Stubbs [the Author of Paper No. 5 (a)]: Mr. Reid Shaw raised the point as to why a richer mixture, a richer application of tar, has not been applied to roads in the Punjab. The answer is that we have 2,800 miles of road to cover and if we put down heavier applications we would never be able to complete our tarring programme. I quite agree that if you put down a richer application you get a longer life. But we find that by putting down an application at the rate of 1/5th of a gallon per square yard for the first coat and of 1/10th of a gallon per square yard for subsequent coats, the results are quite satisfactory and have stood up to quite heavy bullock traffic of roughly about 200 to 300 tons per yard width of road.

Mr. Daniel raised the question about the type of tar that has been used in the earlier applications on roads in the Punjab. To my personal knowledge tar complying with the Road Board specifications was used in 1918 and I used it myself. Mr. Daniel wanted to know what was the object of having written the two papers under discussion. If he had travelled over the Grand Trunk Road between Delhi and Lahore about 5 years ago he would quite have appreciated what purpose has been served by the work we have done now. The Punjab roads have been improved beyond all recognition during the last three years and the two papers outline the methods adopted in order to bring about this vast improvement.

Mr. G. G. C. Adami (the Author of paper No. 6): First of all Mr. Taylor asked about a particular kind of stone of high quartz content that occurs in Assam and which has proved difficult to coat with emulsions. Samples of this stone were sent to us for testing and we could do nothing with it; we sent samples to London and they are still investigating it. The fact is that it has such a smooth surface that ordinary emulsions run off it without depositing a sufficiently thick film; it is rather like trying to wet completely a glass marble with a drop of water. One means of getting over the difficulty would be to increase the viscosity of the emulsion very appreciably but this would lead to other complications such as rate of application being increased, etc. However the matter is still having attention and I hope that some solution will be found in the near future.

Then Mr. Reid Shaw mentioned a whinstone that is also found in Assam that, owing to an earthy streak of decaying rock in the quarry, when broken often has an earthy face on some pieces; they find difficulty in coating these pieces completely. Asphalt will not adhere to dirty stone and this face of the stone being earthy is impossible to coat and there is no means of getting over the difficulty other than rejecting such particles. As a matter of fact the stone that is used by the Bombay Municipality also suffers from this defect but it has been found that provided there is not too high a proportion of such particles no great harm occurs even if some faces are not coated. Such stone gets well embedded in the carpet amongst the other coated stone. The Bombay Municipal Roads are very good and I think are a sufficient indication that no great harm comes from some particles being insufficiently coated.

Mr. Brown brought up the necessity of thorough consolidation of the base, especially where a surface painting is to be applied later. I most emphatically concur with Mr. Brown and am afraid that it is a point that is too often ignored. It is essential to give all roads the

maximum consolidation. Surface painting varies considerably in its wearing properties; in some places it is found that it will carry a surprising amount of traffic without signs of wear, whereas in other instances it fails under much lighter traffic. This I think is directly due to the base on which it is laid. If the base contains only a few stones, especially if they are hard, and a lot of binding material, the stones are apt to cut the carpet from below; all bases for surface painting should consist of the maximum amount of stone and the minimum of binding material so that there will be no sharp points to pierce the carpet from below.

As regards Mr. Parkhurst's remarks I am afraid that he has not entirely appreciated my opinion of the penetration or grouting method. It is a method of construction for carrying considerable intensities of traffic which has proved itself very well in India and I have nothing against it from that point of view. But I do consider that it is a most uneconomical method of construction and just as good, probably better, results can be obtained by other methods mentioned in my paper, at a much cheaper cost. Owing to the excess of binder in the penetration method there is greater risk of failure and ultimate rutting and waving than with pre-mix methods. With regard to Mr. Modak I have a good deal to reply to. In the first place Mr. Modak has rather considered my paper from the point of view of a hot-mix expert who has to deal with city street problems alone: it is not quite fair to compare the type of cold-mix as I have described with hot-mix for there are several fundamental differences. One or two of the examples he quoted in Bombay are actually works carried out during our experimental period—and we are always experimenting—and we are most grateful to the Bombay municipality and its engineers for their assistance at all times for we have learnt many valuable lessons from them.

Mr. Modak brings up the question of the loss of solvent. in my paper I have suggested that no more than 8 per cent. of solvent should be used while in point of fact 4-5 per cent. is generally sufficient Rather more asphalt has to be used in the cold mix types of construction than in hot-mix owing to the higher viscosity of the asphalt. The loss of solvent during the process of setting up results in about the same amount of asphalt being deposited on the road.

Mr. Modak states that he notices that in the cold process the aggregate is measured by volume and not by weight; he said that he prefers the weight measurement. Personally I much prefer the volume measurement for the aggregate because the weight measurement tends to ignore the specific gravity of the stone and sand · after all the function of the asphalt is to coat the aggregate and therefore it is the surface area that counts. Suppose that 100 pound samples of two aggregates of exactly the same grading but of different specific gravities are taken; naturally there will be a greater number of the lighter specific gravity stones in the 100 lbs. than of the heavier stone and therefore the surface area will be greater and so require more asphalt On the volume basis there is no such difficulty and a fixed volume of stone of the same grading but of different specific gravity would have the same surface area. I think that there are often mistakes made in hot-mix where the aggregate is kept to a fixed grading but where for one reason or another a different stone of higher or lower gravity has to be substituted for the original aggregate; generally the bitumen content is calculated on the grading and so no alteration is made although the surface area

has been altered. I strongly recommend that the volume basis for measuring aggregate should be adopted

With regard to the asphaltic concrete on Sandhurst Bridge having failed after two years, I would point out that this was the cold process. carried out in a hot-mix plant and, owing to the higher temperatures there was considerable segregation of the stone and sand. I think that after seeing the work in progress on the Rohtak Road everybody will agree that if properly carried out there is no segregation with the cold. process.

On the question of filler, filler can be put in in the cold process. without much difficulty. It is rather doubtful whether at present on most of the jobs carried out on this process a filler is justified because the addition of the filler necessitates an increase in the quantity of binder to be used. As regards the two coat surface dressing, the objection to this type of construction is not only cost, a ½ inch film is too thin to cope with any appreciable unevenuess in the base. Municipal roads in such a town as Bombay where asphalting has been in progress for a number of years, are naturally almost free from unevenness and therefore this consideration probably does not weigh heavily with Mr. Modak, but it is a most important one so far as mofussil roads are concerned. But two coat surface dressing is an expensive type of construction when it is appreciated that a 1 inch mat can be laid by pre-mix processes at a lower cost.

Diwan Bahadur N. N. Ayyangar: I want to know whether a seal coat of Spramex is necessary for Shelcrete.

Mr. G. G. C. Adami: That is a question I have been asked several times; a seal coat is not necessary in Shelcrete as the sand works up to the surface. You have all seen Shelcrete Roads around Delhi in various stages of the sealing process and you have seen that Shelcrete does seal itself. The probable effect of a seal on Shelcrete would be a rich surface as the sand would still work up and this would mark under traffic. A seal is only justified if the monsoon is to come immediately after completion of the work and even then it should be extremely thin.

Diwan Bahadur N. N. Ayyangar: In Bombay Shelcrete was done last year and I heard just now that the top was failing and I learn that it is an advantage to have a thin film of Spramex.

Mr. G. G. C. Adami: I will find out about the particular road to which you are alluding and will let you know; I understand that you said it was on the Thana Road. If what you say is correct there must be a particular reason for there are Shelcrete roads, in the Bombay Port Trust, now nearly four years old which carry very heavy traffic and which have required neither a seal nor maintenance.

The Congress then adjourned till 2-30 P.M.

The Congress re-assembled after Lunch, at 2-30 P.M. with Diwan Bahadur N. N. Ayyangar, Chief Engineer and Secretary to Government, Mysore, in the Chair.

Mr. K. G. Mitchell: Gentlemen, before we start I should like to say that there is a further change in the programme. It seems to be the general opinion and desire that we might finish to-morrow afternoon. The thing that we must do is to receive the report of the Committee regarding the future constitution and so forth, and the Committee has yet to make its report which is now ready, and I hope it will be in your hands before you leave this afternoon. We have therefore decided to have the discussion of that at half-past two to-morrow afternoon. If we have not finished all the papers by then, we shall have to break off after discussing the report; because, after all, it is a very important thing, and if anybody wants to go to-morrow, he can do so. I think this afternoon we shall probably be able to finish the papers unless the discussion is very long. I see that the congregation is apparently suffering from indigestion (Laughter) or something of that sort, and if you will not mind you might tell everybody you see, that to-morrow afternoon you will see the doings and future constitution of the Congress and so forth.

Chairman (Diwan Bahadur N. N. Ayyangar): Gentlemen, we will proceed with our business, and we will take up Paper No. 10 which will be introduced by Mr. Greening on behalf of the author who has not been able to attend the Congress.

The following paper was then submitted for discussion.

(*Paper No. 10*)

Corrugation of Water-bound Macadam Road Surfaces in the Bombay Presidency, and a Cure

By

Henry J. M. Cousens, Superintending Engineer, Bombay Presidency.

1. This note deals with the transverse corrugation of water-bound Macadam road surfaces in the Southern and Central Circles of the Bombay Presidency where the roads are mostly surfaced with trap (Basalt) metal. Laterite is used in some Districts where trap is not available and quartz metal is used in very small areas in the Southern Circle where that is the only material which can be got. The metalled widths of the roads vary from 12 feet to 16 feet as a rule but are wider in and near the larger towns. The metalled widths are flanked on each side generally with muram side widths about two feet wide. The binding material for trap metal is generally muram and when that is not available a red or brown soil is used. Laterite binds itself. The finished surfaces are blinded with sand, muram or brown or red soil. Corrugations are not universal but only occur in certain miles. The heaviest traffic on the roads is that of bullock carts and public motor buses.

2. The corrugation of water-bound Macadam road surfaces has engaged the attention of Engineers in recent years but no definite cure has till now been discovered. Since my first appointment as Superintending Engineer in October, 1931, I have had the opportunity of carefully studying all the Public Works Department roads in the Southern and Central Circles of this Presidency and have found that the use of sand as blindage, either by itself or mixed in other blindage, is the cause of corrugations.

3. If sand is eliminated there are no corrugations. The worst corrugations occur when the blindage is entirely sand. The less sand in the blindage the less the corrugations. With muram, brown earth or red soil free from sand there are no corrugations. Wherever there is a tendency to corrugate, *i.e.*, wherever there is sand, the speed of mechanically propelled vehicles is a contributing factor to the corrugations of the road surface. The greater the speed the worse the corrugations. In the Southern Circle there is hardly any sand used as blindage as it is generally not obtainable. Practically all the roads there are blinded with brown or red soil or muram. The roads there are remarkably free from corrugations. These exist only in an occasional mile where a little corrugation is noticeable due to a small admixture of sand in the blindage or in miles where sand happens to be used.

4. In June, 1930, as Executive Engineer, Dharwar Irrigation Division, I wrote as follows to the Superintending Engineer, Southern Circle, in connection with this matter :—

" Assuming that the road surface is thoroughly consolidated, as *it should be* with the aggregate pieces in as intimate contact with the surrounding pieces as possible before any binding is applied, and that the foundation is good the corrugations are first started by slight unevennesses in the rolling which cause

vertical oscillation in motor vehicles travelling on the surface due to the play in their springs. If there is loose blindage on the surface this results in that blindage being pushed back with the backward thrust of the driving wheels in waves corresponding to the upward and downward oscillation of the wheels, and a regular series of waves with distances between crests of from 18 to 24 inches is a result of the original uneven surface. If these waves, formed of blindage, are not removed regularly, as soon as formed, the pounding action which they induce eventually acts on the hard road surface itself and causes that to form into waves also, so matters go from bad to worse. A badly rolled surface therefore causes serious trouble and needs constant attention and expenditure of money to keep it to its original smoothness. It is therefore essential that the finished surface after consolidation should be free from waves. The heavier the motor vehicles and the greater their speed the greater the damage, as the thrusts they transmit to the road surface are so much greater in proportion. Heavy motor vehicles of the public bus type should have their speed considerably restricted. Their present speeds are far too great for our roads to stand up to."

5. Not all the sand blinded miles produce corrugations. Whether corrugations are produced or not depends on :—

(a) the speed of the mechanically propelled vehicles ; and

(b) the number of such vehicles using the road compared with the number of vehicles of other types.

If the speed of mechanically propelled vehicles is not high, corrugations do not form ; this is shown by their absence on roads through towns or on ghat roads where bends are frequent and speed is naturally reduced. Sand can therefore be used on such stretches of road without fear of trouble resulting. If bullock carts and other animal drawn vehicles predominate, the corrugations that are formed by mechanically propelled vehicles are quickly dispersed by the cart wheels and hoofs of the animals. This is particularly noticeable on the roads in Khandesh where there is very heavy bullock cart traffic and at the same time quite a number of motor buses. The bullock carts there use the full width of the road and the surfaces, though sanded, generally remain smooth. There are very few miles there with corrugations. On other roads again one finds sanded miles corrugated in the centre only, as the sides are used by bullock carts which keep these widths smooth.

6. At the beginning of this year I issued instructions to the Executive Engineers in my Circle in the matter. They have been informed how sand blindage, or sand in the blindage, tends to cause corrugations and have been directed to use *soft* muram, or brown or red soil free from clay or sand where muram is not available as blindage, on all roads in future *where there is any tendency for corrugations to form* (clay soil being rigorously excluded, particularly black soil). The change over is now taking place and I hope corrugations will have practically disappeared by the end of the monsoon, by which time it is hoped the sand in corrugated miles will have been entirely eliminated. The Poona Satara Road being a particularly bad one as regards corrugations, I decided to spend Rs. 1,000 on removing them from those miles in which the metalled surface had not so far been much affected by the pounding action of

vehicles going over them, as this would save considerably more in the end than in repairing the damage afterwards. This has been done and muram has now replaced the sand. A very considerable improvement indeed has resulted giving smooth running for a car over all those miles. Slight corrugations will still form until all the sand is eliminated, but these will soon disappear. Where the metalled surfaces have been damaged as a result of long continued pounding action on them due to corrugations, such miles will not be satisfactory until they are resurfaced. As many as possible of these damaged miles are now being remetalled.

7. Sand proved an excellent binding material in the past for slow moving vehicles, but due to the tendency the heavy particles have, under fast motor traffic, of being brushed back to form regular corrugations, it has now to be abandoned where corrugations tend to form. The much lighter particles of the soft muram or soil blindage do not form these regular waves. There may be more dust due to the change-over on those miles where that has to be done, but that will be infinitely preferable to corrugations, and it will be no worse than motorists suffer in the Southern Division. The dust trouble will, it seems, have to remain until the surfaces can be asphalted or concreted.

Addendum.

Since writing this paper in October 1933 Mr. Cousens has had further opportunities of observing the results of his remedies and wishes to add that these have been very satisfactory and that the elimination of sand from road surfaces, where there is any tendency to corrugate, definitely eliminates it.

Mr. L. E. Greening (on behalf of the Author of Paper No. 10): Mr. Chairman and Gentlemen, I am afraid I have no remarks to offer on Mr. Cousens' paper. but yesterday morning I received from him a letter which he wished me to read before the Congress in continuation of his Paper. I will now read it.

"The elimination of corrugations by the method advocated in the paper has been entirely successful, as observed by me in my tours last month. The 130 miles of the Poona Bangalore road in my jurisdiction which was the worst road in this respect, is now entirely free from that trouble. In only a very few miles of it there is just the *slightest* trace of corrugations, but this is due to sand not yet having been entirely eliminated from those particular miles, due either to (1) the harder muram used producing gritty particles of the nature of sand. or (2) sand still working up by suction from the binding of the metalling. (1) is being put right by using a more suitable quality of soft muram or earth and (2) will gradually disappear. One can now motor over the Central Circle roads without noticing any corrugations".

Chairman: Has anybody else any remarks to make?

Capt. G. F. Hall: I admit I do not know much about roads outside Bihar and Orissa and in spite of the many miles of surfaced roads we have seen on our recent tour in the Punjab, N.-W. Frontier Province and round Delhi, I imagine that the great majority of pucca roads must be of water bound macadam. Though in the course of time they may be improved to higher grades they will be with us many years to come, and I submit that their maintenance to withstand the wear and tear of heavy and fast traffic is an important matter for the consideration of this Congress.

I have read Mr. Cousens' paper with more interest than conviction in his contention that the substitution of moorum for sand blindage entirely eliminates corrugation. In Bihar and Orissa we use moorum almost exclusively for the blindage of our water bound macadam roads but corrugation occurs on most of them. In 1933 I was officiating Superintending Engineer of the Chota Nagpur Circle and was in charge of about 800 miles of water bound macadam roads of which about 715 were unsurfaced. In the March 1933 number of "Indian Roads", Mr. Pipe, Executive Engineer, Bombay, published an interesting and instructive article on road corrugation. He expounded his theory as to how corrugations were formed and gave the results of his own observations. He stated that the spacing of waves varied from 26″ to 32″ but that it was invariably constant over a particular length of road. Mr. Cousens observed waves of 18″ to 24″ only. Mr. Pipe advocated speed restriction as the only remedy.

I took his article out on tour with me and spent some days comparing his observations with my own on several corrugated sections of the G. T. road. They differed considerably. I did not find ridges formed above the surface of the road but that corrugations were formed by depressions. Mr. Pipe contends that corrugations are formed by fast cars throwing up the blindage into ridges. I had a section of road sprinkled with moorum containing sufficient loose stones to cause oscillation of car springs. I made sundry experiments with slow and fast moving traffic with the moorum both dry and wet but in neither case did I find any ridges formed. This is as Mr. Cousens discovered, but, as I said before, our Bihar and Orissa moorum-blinded roads do corrugate.

I also took a number of measurements of corrugations on the flat and on the slope. Nowhere did I find regular waves. It was the exception for two consecutive corrugations to be the same. I found corrugations

varied from 13″ to 44″, with 33″ slightly predominating. The corrugations were rarely at right angles to the axis of the road but varied from 20 to 30 degrees from it.

I found corrugations far more severe in lengths metalled with quartz. which circumstances compel us to use extensively, than in those metalled with harder stone. This was as anticipated. I came to the conclusion that it was the slow moving traffic with iron shod wheels, rarely true on their axles, that caused the initial attrition and that the fast moving traffic did the rest.

I wrote an article in "Indian Engineering" which was published in the issue of September 2nd, 1933, describing my observations and expressing my views. While I was making these observations I instructed one of my Executive Engineers, Mr. S. K. Roy, to make his own independently. He came to the conclusion that the initial rolling was entirely responsible for corrugations and that they could not be eliminated. To test his contention we rolled about a furlong of road with extreme care and no corrugation was visible to the eye or betrayed by templates. We kept all traffic off it and some nights later Mr. Roy made an experiment with the aid of a spot light and mirror and his apparatus revealed the presence of corrugations.

Incidently, while on the subject of rolling, I am convinced that we roll our quartz too long and with too heavy rollers and cause initial attrition by damaging the edges of the stones.

In reply to my article, Mr. Murrell, Executive Engineer, Bihar and Orissa, published another in "Indian Engineering" of October 7th, 1933, in which he disagreed with both Mr. Pipe and myself and attributed corrugation to defective sub-grade drainage though I had no fault to find with the drainage of the roads in question. But he also strongly supported Mr. Pipe's advocacy for speed restriction by the use of governors on mechanically propelled vehicles. I am personally opposed to speed restriction except on the grounds of public safety. The traffic of the future is going to be fast and it is our duty, as road Engineers, to improve our roads to stand up to modern conditions and not force traffic down to our present levels.

Since this Congress was convened Mr. Little, Executive Engineer, in the Sholapur District has published an article in "Indian Engineering" of November 24th, 1934, entitled "A Revolutionary Experiment in road surfacing". He seems to have gone further than any one else to date in the solution of the corrugation problem and his treatment is worthy of being tried out on a large scale. Briefly, instead of rolling in his binding moorum from the top with only partial penetration, he lays his moorum at the bottom of the metal and rolls till it comes to the surface, with apparently vastly superior binding properties. He claims that in attempting to pick up the surface 6 hours later he turned the point of the pick.

My remarks are intended to show that many road Engineers are interested in the problem but their results and views do not coincide. It also only too frequently happens that owing to transfers, leave or difference of interests, experiments are not continued and much useful labour is lost.

I consider that part of the Petrol Tax Fund allotted to each Province should be set aside exclusively for experiments by selected officers and that Chief Engineers should insist that all experiments are continued when any officer goes on leave or is transferred; results being collected and pooled through this Congress.

As regards corrugation, it is unlikely that any one method will suit all conditions but it should be possible for us to arrive at the best solution for any given condition.

Mr. H. Hughes: In Burma, a similar difficulty to that described in Paper No. 10 has been experienced by topping or blinding rearing into corrugation. The conditions were similar to those described in the paper, *i.e.*, a water bound macadam road 12′ wide on which the traffic consists of 80 per cent. of motors. The rainfall varied from 50 to 200 inches per annum. Owing to this rainfall it is neither necessary to spread topping during the rains nor would it stay on the road. The conclusions drawn by the engineer in charge of the sections where corrugations formed were that they were due to the following causes, firstly the topping being spread too thickly, secondly the topping containing silt or clay and thirdly the topping which had been dispersed by passing vehicles being scraped back on to the road into ridges across the road. The remedies tried which proved satisfactory were "(1) to spread the topping in very thin layers and on the wheel tracks only, (2) to insist on the topping being spread along the length of the road, and (3) to use washed sand from which silt clay had been removed".

Mr. K. G. Mitchell: Is there any member of the Central P. W. D. who is in charge of the maintenance of Kingsway here? This has nothing but motor traffic. It has got a red gravel top and frequently corrugates. It has got red gravel dressing and nothing else.

Chairman: Gentlemen, this is a very interesting paper and after all is said about various kinds of surfaces, we have to depend upon macadam surface ultimately on a major portion of our roads. The cause of this corrugation, so far as I can think personally, is this. The rear wheel of any motor vehicle is driven by the engine. In propelling itself, it has to react against the road and therefore it produces an abrasive action on it, and any soft surface like gravel or earth or macadam surface is bound to get worn in that characteristic way as corrugations and I do not think it is possible to obviate these so long as we have got only the macadam surface and the motor traffic is heavy and moves at high speed. The author says that no definite cure has till now been discovered. I do not think it can ever be discovered so long as we have a macadam surface. The only obvious remedy is to use tar, bitumen, cement or if you please, Mysore slabs for these roads. If you have only the sand blindage, the corrugations occur earlier as sand has no binding property. But if you put clay, the process is slower because clay has got binding property and when it gets wet and dries, it gets hard. When there is blindage the corrugation first appears only at the surface. As time goes on, what happens is that corrugation enters the macadam surface. When you travel at night in lamp light you see the corrugations very vividly. There is no regular system under which they are formed. The surface simply wears off owing to the jerky motion in which the rear wheel has to travel. It is due to the periodical internal explosion in the engine. The impulse is periodical and it is transferred to the wheel also periodically. So the wear also is in jerks and that seems to be the real reason for this corrugation and, as I have already said, there is no remedy except by improving the road surface by means of tar, bitumen, cement or any similar materials which can stand abrasion better. We have no money and we have still to go on with macadam road surfaces and the only remedy that I can think of under the circumstances is renewal of the surface oftener after a light picking of the surface with just a thin coat of new metal added. Beyond that I do not see any other solution. Before closing we wish to express our thanks to the author of the paper for the very interesting subject that he has brought before us.

Chairman: We shall now take up Paper No. 12.

The following paper was then submitted for discussion.

(*Paper No. 12.*)

Some Physical Aspects of Tyres and Roads

BY

G. L. W. MOSS,

Dunlop Rubber Company, Ltd., Bombay.

The last 15 or 20 years have seen a phenomenal advance in the development of vehicles for mechanical road transport. This advance has not been marked by any revolutionary changes in the type of power unit and chassis employed, but is the outcome of a continuous series of improvements in the design of their component parts. Of major importance have been those relating to pneumatic tyres which are, at once, the ultimate load carriers, and the agents giving effect to the motive power of the engine and retarding power of the brakes. When it is realised further, that these functions are only incidental to the primary one of acting as part of the springing system interposed between the road and the chassis, their importance needs no emphasis. It is difficult to conceive in what form mechanical road transport would have developed without them.

2. The economic advantages of a modern road vehicle cannot be exploited fully unless an efficient system of suitable roadways is provided. These must be cheap to construct and durable in character. As the physical problems of tyres and roads are so closely inter-related, the following paper is intended tc present some of their general aspects (especially those with reference to tyres) in a form which it is hoped will be easily understood. Most of the subject matter has formed part of the ordinary business of the Dunlop Rubber Co., Ltd., to whom I am indebted for permission to contribute this paper.

3. *Cushioning Capacity of a Tyre.*—Apart from its behaviour as a structure for carrying a load and transmitting acceleration and deceleration stresses, it is the function of a tyre to absorb shocks which would otherwise be imparted to the chassis by small irregularities of the road surface. This absorption is effected by reason of a tyre's cushioning qualities which are determined by its ability to deflect under increasing load. on a flat surface. This method of measuring cushioning capacity, and hence gauging the riding-qualities, is not in accordance with what might be expected from an interpretation of the general belief that a tyre behaves as it does because of its ability to absorb or envelop obstacles.

4. Any obstacle actually capable of envelopment by a tyre cannot, at ordinary speeds, produce a verticle thrust of sufficient magnitude to impart a noticeable shock to the chassis. Returning then to the measurement of cushioning capacity, it is interesting to note the difference in characteristics between solid and pneumatic tyres: this formed one of the two chief reasons why the general use of the solid was discontinued.

5. *Cushioning Capacity of a Solid and a Pneumatic Tyre.*—If a solid tyres is progressively loaded by equal weight increments, the amount of deflection

for each increment becomes progressively less until a point is reached when any further increase produces no appreciable effect. With a pneumatic tyre, however, the amount of deflection is practically constant over the whole of the useful load-range so that it conforms very closely to the properties exhibited by a coil spring.

6. The condition of rigidity approached by the solid at its full load renders its further possibilities as a good cushioning medium quite negligible. This disadvantage is exaggerated by over-loading, or by a part-worn state of wear in which the effective rubber depth is, of course, decreased. In comparison, the deflection characteristic of the pneumatic indicates equal cushioning capacity at all loads, and since only the protecting outer cover of the complete tyre is destroyed during service, this cushioning capacity remains unaltered throughout the cover's useful life.

7. *Road Stress.*—Poor cushioning capacity has considerable ill effects on the vehicle due to the harshness of the shocks imparted, and no one who has watched the wheels of a solid tyred vehicle proceeding along a road, or felt the heavy vibrations accompanying its passage will doubt either, that it has considerable ill effects upon road structure. Solid rubber and steel tyred vehicles are indeed the real road destroyers.

8. In view of the heavy financial aspect of road construction and maintenance it is not surprising that certain countries have introduced legislation either prohibiting solid tyred vehicles on public roads altogether, or offering such inducement in the way of reduced taxation in favour of pneumatics that the fitment of solids is made quite unattractive. In these countries the adoption of pneumatics and the development of their use at lower pressures must have been very effective in reducing the average cost of maintenance per mile of road.

Some interesting observations are made by the Highways Commission of the United States following experiments to determine road stress, etc., at the various loads and speeds common to pneumatic tyred commercial traffic. These experiments were recorded using High Pressure tyres. The Commission states :—

1. Any road thickness determined as sufficient to withstand weather erosion or a given period would also carry satisfactorily vehicles up to 6 tons gross weight.
2. That by increasing the thickness 15 per cent. it would carry the maximum pneumatic tyred loads.

The American Bridge and Road Engineers find from a study of impact curves in the road foundation :—

A. That if the number of axles of a vehicle is increased, and its load increased accordingly, the maximum road stress is not necessarily increased.

B. That the magnitude of verticle shocks increases with the speed up to 30 miles per hour but decreases above that.

These findings (1, 2 and A, B.) do not indicate any limiting factor to the possibilities of the development of bigger and faster vehicles and certainly, in as far as pneumatic tyres must play a very important part, the ingenuity of the manufacturer is by no means exhausted and he will not fall behind any of the other interests directly involved in its problems.

Running Speed and Temperature of Solid and Pneumatic Tyres.—It has been stated that difference in cushioning capacity was only one of the two chief factors which led to the demise of the solid tyre. The other was its inability to withstand speeds higher than about 20 miles per hour for the rubber became disintegrated by heat and failures were frequent.

The pneumatic suffers no such disability: the reasons are as follow. The cycle of compression and recovery which each part of either a solid or pneumatic must pass through once in every revolution of the wheel, consumes a certain amount of power in overcoming the internal friction of the material comprising it. This loss of power reappears as heat, and the rate at which the latter is dissipated from a particu'ar point in the body of the tyre will depend upon the thermal conductivity of the material, and the proximity of the points to the tyre surface.

9. The thermal conductivity of a rubber compound is very low—little better than that of dry wood. While this constitutes an equal disadvantage for both tyres, if we compare the thickness of a pneumatic and solid tyre designed to carry equal loads, any point near the centre of thickness of the former—which is obviously where the temperature is likely to become highest—will be nearer the surface than a similar point in the latter. Hence at the maximum speed possible for the solid tyre the pneumatic runs considerably cooler, and, in fact, its speed can be increased to a point outside that generally required, or possible for a modern truck because eventually, the rate of heat dissipation will equal its rate of generation, and the resulting temperature still remains below the critical one attained by the solid. It will be noted that the difference in temperature characteristics is due to difference in thickness, and not power consumption. Actually the latter is somewhat higher in the pneumatic tyre.

10. *Cushioning Capacity in relation to Pressure and Section.*—The reasons for the increased cushioning qualities and higher permissible speed of the pneumatic having been explained, it will be interesting, in view of the continued development in the direction of larger sections and lower pressures, to indicate the effects of these changes on pneumatic tyre behaviour.

11. As is well known, the cushioning capacity of a tyre can be increased by lowering its inflation pressure: when dissatisfaction with riding comfort arises, this is indeed automatically resorted to. It is also dependent on the cross-sectional width, for if the capacity of two tyres of different cross-section are compared at equal pressures, that of the larger has the smaller value. This means that if a reduced pressure, satisfactory from the point of view of comfort (but not tyre life) is found for a small tyre, and a larger tyre is then substituted to operate at the reduced pressure, the same degree of comfort will not be obtained and a further lowering of the pressure must be made.

12. A little thought will make it clear, therefore, that in a change of tyre equipment from which an appreciable improvement in riding comfort is contemplated, the difference in pressure between the old and new tyre must be great enough not only to provide the obvious advantage to be expected from the use of a lower pressure, but also to mask the disability accompanying the use of the larger section itself, as such. This accounts for the wide difference in pressures as between the High Pressure and Low Pressure or Low Pressure and Extra Low Pressure tyre ranges.

10. *Damping Capacity and Power Consumption.*—We now come to a consideration of the damping characteristics of a tyre which affect its ability to damp out oscillations. To make the meaning of this property clear we may illustrate it. If a weight is suspended on a thin coil spring and set moving with an upward and downward motion, it will continue to oscillate for some time before coming to rest. If the operation is repeated with the weight and spring immersed in a fluid (*e.g.* oil), part of the potential energy of each oscillation will be consumed in displacing the fluid itself which will thus act as a damper and bring the weight to rest more gently and in less time than before. By an inherent virtue (from the nature of its materials) and not design, a pneumatic cover acts similarly in damping out the oscillations of a vertically displaced axle. Its efficiency, however, varies with type, and the modern Extra Low Pressure is less efficient than the High Pressure in this respect. That this is so is readily apparent, for modern cars are fitted with "shock absorbers" or "dampers" to supply an extra damping effect never found necessary with the old High Pressure type.

14. A tyre's damping ability is connected with its power consumption but not in a very obvious manner. Returning to the illustration given by a spring-suspended weight immersed in fluid it will be reasoned that if the proportion of energy lost in displacing the fluid increases in relation to the total energy of the oscillations (such as would occur by using a thicker fluid), the damping effect would be greater. Such is the case, but it is to be noted that the actual value of the total and lost energies does not matter: It is only a question of their relative proportion.

15. Now if a High and Low Pressure cover of the same thickness are run at equal load and speed (but appropriate inflation pressure) the deflection of the low pressure cover will be the greater, and, therefore, the total resistance of the cover to deflection, or its power consumption, will be greater, but due to the smaller ratio of thickness to cross-sectional width the Low Pressure cover is a much more flexible structure and the proportion of power consumption lost by internal friction is less. When increase of deflection and section is carried a stage further as in the Extra Low Pressure cover the power figures increase in magnitude but become more divergent in proportion. The high power consumption and the low damping value is therefore understood.

16. *The Road and Tyre Contact Area.*—It is generally thought that as the air-pressure within a tyre is constant at all points, the road pressure over the contact area is also constant, and that the contact area multiplied by the inflation pressure would give the tyre load. This is not the case,

for the geometry of a tyre is complex and can be varied within wide limits according to the view of the designer: its material is not uniformly stressed under deflection.

17. For practical purposes the shape of the area of contact is elliptical: any tyres of equal overall diameter, irrespective of inflation pressure, or section, will, if deflated by an equal amount (say one inch) have the same length of contact. But the width of contact cannot possibly be wider than the width of the tread which is arbitrary. Obviously, therefore, if the tyres carry the same load, a low pressure cover with a comparatively narrow tread would give a low pressure-area product while a high pressure cover with a wide tread would give a high product. Neither would equal the load carried. Eliminating air pressure therefore, the most that can be got from the relation between contact area and load carried is the average road contact pressure per square inch.

18. *Intensity of Pressure in the Road Contact Area.*—The variation above and below this average pressure is fairly great and is influenced both by the curvature across the tread, and the pattern. The rounder the tread, the higher will be the intensity of pressure in the centre of the area. If the tread is less round and wider, and the deflection increased (such as for example, may be considered to be the case with a Low Pressure cover) the intensity at the centre is decreased while a corresponding increase occurs at the edges.

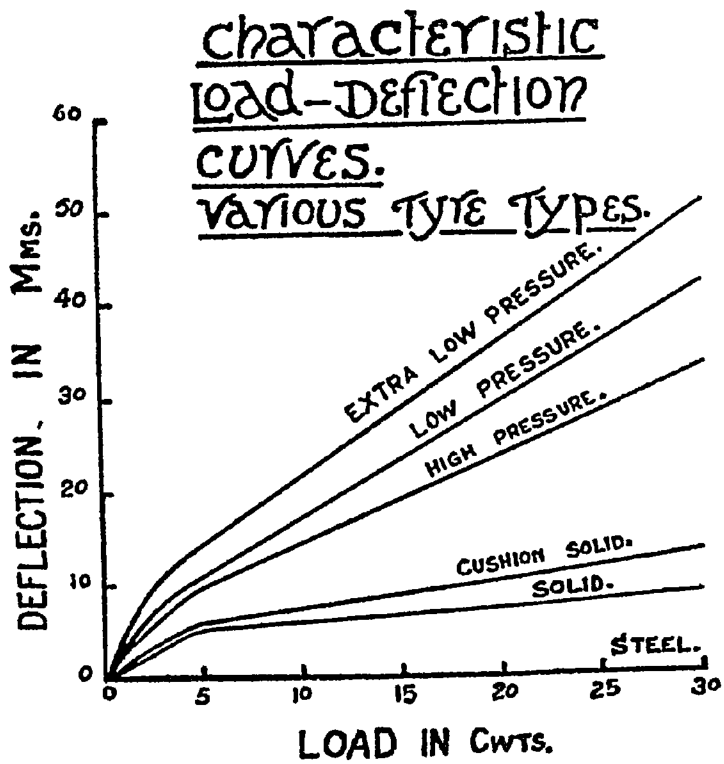
19. The better anti-skid properties of Low Pressure and Extra Low Pressure tyres, compared with High Pressure, is attributed to these differences since any lubricating film present on the road will be scraped away as the tyre commences to slide, and thus provide a clean surface for the "follow-up" area. Road contact-pressure can also be modified by alteration of tread pattern characteristics, for obviously if the portions cut away (*i.e.* the grooves of the pattern) are different in two tyres otherwise alike, the contact pressures at local points will vary between them according to grooves size and disposition.

20. *Surface Road-Wear.*—The rate of "break-up" of a thin lamina of a hard road surface or "cutting-up" of a plastic one must decrease for the same load carried if the contact area of the tyre supporting it is increased. The average road pressure of the pneumatic tyre is obviously much less than that of an iron tyre (such as fitted to a bullock cart) which approaches a line contact. This is true, even if only the local areas of High Pressure contact in the pneumatic are considered because the rubber pattern-blocks increasingly distort themselves as the road pressure increases, and thus tend to restore pressure equilibrium.

21. At the same time, as the tread commences to leave the road, the recovery of the pattern-blocks from distortion causes a slip, and hence an abrasive action between them and the road surface, evidence of which is easily discernible in the form of wear the pattern blocks take. It will be realised that an abrasion of the road surface accompanies that of the tyre tread. The amount depends upon the nature of the road materials, but whatever this may amount to, it would be contrary to reason and common observation to say that it was equally, or even as remotely, destructive in its effect as the pulverising and cutting action of the iron tyre.

Mr. G. L. W. Moss (the Author): I have not very much more to say beyond what I have already mentioned in my paper. From its perusal you will gather that the chief physical characteristic of a tyre from the point of view of the road engineer is its cushioning capacity. I have fairly dealt, with the difference in cushioning characteristics between a solid tyre and pneumatic tyre; an important difference which led eventually to the demise of the solid. I need hardly say that the steel tyre of bullock drawn vehicles has no cushioning capacity whatever. We have witnessed very important developments in tyre construction in the last two or three years, chiefly in the adoption of larger section pneumatics for use at lower inflation pressures. These lower pressures still further improve cushioning capacity. I would like to illustrate this question of cushioning capacity by means of a graph which will explain in a few minutes what otherwise requires some considerable time.

Here the author drew a graph which is reproduced below—



I have purposely refrained in my paper from giving figures. You will realise that the many different sizes of tyres, and the differing conditions under which they work, makes the question of selection a difficult one but if any members would like particular figures for definite types or sizes of tyres, I shall be very pleased to give them.

DISCUSSION ON PAPER No. 12.

Mr. O. H. Teulon: Mr. Chairman and gentlemen, the exhibitions which the Dunlop Tyre Company have given us on the roadside, as we have gone along, of their tyres have all been under dry conditions. What I should like to ask Mr. Moss is, what happens during the monsoon? In Burma the mud is inches, if not feet, deep in many places and the Burmese cart wheel has a very narrow tyre and the construction of the wheel is also narrow in order that they may cut through the mud and reach possibly harder grounds, so that they can move along at all. Is the bearing surface of the new air wheel sufficient to support the load in such circumstances where you have several inches of mud to contend with? If not, the introduction of the air wheel to the agriculturists in Burma is quite out of the question because the carts must go on to the fields as well as on to the roads. I shall be very glad if Mr. Moss can give us some information on this point.

Mr. K. G. Mitchell: I would like to ask Mr. Moss one question. Are these typical graphs drawn in respect of a point load or in respect of a natural tyre resting on a surface? Because in the latter case, as the tyre deflects, the area of contact increases and I do not think it would be a straight line.

Mr. G. L. W. Moss (the Author): Those curves relate to pneumatic tyres at constant air pressure and the increase in contact area does not effect them. The area of contact does not alter in relation to the load applied because the width of contact is constant as determined by the thread width. If you have an increase in deflection or load, you merely increase the length of the major axis of the ellipse of contact but that increase does not bear any direct relation to the increased load which you apply. It depends more upon the stiffness of the material itself. For all practical purposes you may take it that the load deflection curve is a straight line.

Chairman: I too would like to ask one or two questions of Mr. Moss about these tyres. Generally, in the case of pneumatic tyres, we speak of suction action. Is that correct? I am inclined to think that the description of the action is not correct, because if that were so, the solid tyres would be better than pneumatic tyres. How, in the former case, can suction occur? We know that the same destructive action takes place on the road whether it is solid or pneumatic. You may perhaps say, because of the weight the tyre gets depressed when the load is directly on a point and throws out the dust in the act of recovering. In addition, dust is thrown out by the rain due to centrifugal action also.

One other point is that in all your trials with bullock carts, you have been using pneumatic tyres. I cannot see why you went out of your way to provide pneumatic tyres for bullock carts. In these cases the trouble is the axle and the hub. You have nice ball-bearing hubs fitted to the axles of the wheels and if you only fitted solid rubber tyres I think the agriculturist would take more kindly to it and you would do much better

business and afford much more benefit to the agriculturist. I suggested this point more than once to the people concerned in Bombay and also in Mysore and I mention the matter once again here.

Mr. K. G. Mitchell: I am sorry I forgot one thing I would like Mr. Moss to deal with in replying to the discussion. Some years ago in the Brunswick experimental test track, they suggested various materials. I think it was definitely established that low pressure pneumatic tyres were far more destructive than high pressure tyres. Perhaps Mr. Moss will deal with that point

Mr. A. W. N. Dean: Is it not a fact that considerably increased draught is required for the same load with low pressure than with high pressure tyres and that the extra tractive effort may therefore damage the road somewhat more? It seems to me there is a direct relation between the tractive effort of a tyre on a road and the destructive effect of a tyre on the road.

Mr. G. L. W. Moss (the Author): I have been asked whether pneumatic wheels for carts used on muddy surfaces would be more or less efficient than the ordinary type of wheel. The great advantage of pneumatic equipment, of course, is that on ground in a semi-muddy state, one can by lowering the inflation pressure obtain an increased and concave contact area so that the tread of the tyre cups itself and that has a binding action in the ground over which you are pulling. The tyre will therefore slide over the muddy soil rather than sink and increase the required draught. If, of course, the ground is so watery that compression is impossible, no type of tyre would be either more or less efficient than another. With pneumatic equipment, it is true that you would have a wider section of tyre sinking to the firm foundation and I presume therefore that a slightly greater effort would be needed to draw the pneumatic tyre under these conditions. The great point is however that when traction over certain surfaces is utterly impossible with an ordinary type of wheel (because it has to sink to such depths to obtain firmness that it is impossible for the cart to be drawn at all), where these conditions prevail, the pneumatic tyre enables them to be negotiated with more or less ease.

From experiments which have been carried out on ploughed land it is found that the draw-bars pull for pneumatic tyred farm carts is about one-third of that required for steel tyred carts. That of course is a very appreciable difference. On very hard and smooth surfaces, the advantage is still with the pneumatic tyre but it is not so highly marked; but even so the draw-bar pull is perhaps in the region of 20 to 25 per cent. less than for steel tyred carts.

The question of slippage or, as the Chairman has described it, the suction of the dust on the road, amounts to this. What actually happens when the tyre is in contact with the road is that the pattern closes up partially. This is to be expected because the arc of the tread is compressed into a chord length. When the tread begins to leave the road the pattern releases itself again and promotes the slipping action of each independent pattern-block. This action combined with agitation of the air by the revolving tyre tread raises a dust cloud. Actually there is no suction of the tyre tread as such.

Solid tyres could not be advantageously adopted for bullock cart, for the reason that on soft ground they have no advantage at all in tractive effort over the ordinary type of steel tyres. In addition a mere change from steel to solid rubber tyres would not give any appreciable advantage in cushioning capacity.

With regard to horse-power consumption in relation to lower inflation pressures, it is quite true that the consumption does increase as the more the tyre is deflated the more is the power consumed in the material of the tyre itself. In the case of ordinary motor car tyres say the 5·24 section on a car travelling at 35 miles an hour, each tyre will absorb about three quarters of a horse power. If you change the 5·25 section to 7·00 at a very much lower pressure, the horse power will increase to about one horse-power per tyre which is an increase of 33⅓rd per cent. However, although these horse power figures look rather alarming, they are not very important. Power losses due to tyres are only about 30 per cent. of the transmission losses in a car. Some people have found that with tyres at very low pressure an increase in petrol consumption from 6 to 7 per cent. has resulted. I have even heard it expressed as high as 15 per cent. but actually one would not normally expect an increase in petrol consumption exceeding 8 per cent. In any case, the advantage of extra low pressure tyres in regard to riding comfort is so marked that whatever disadvantages arise they are gladly accepted.

I am afraid, I did not quite understand your point, Mr. Mitchell, with regard to relative road wear between high and low pressure tyres.

Mr. K. G. Mitchell: It was proved I think conclusively on the Brunswick test track some years ago. If you like I will send you the particulars. It is all in German if you can read it. I suppose it was due to the slip.

Mr. G. L. W. Moss, (the Author): It is possible that the question of pattern slippage with regard to road wear is important. It is also important to the tyre manufacturer because the pattern slippage determines (more or less) the tread wear. Obviously the tyre manufacturer has to produce a tyre which is going to give a reasonably long life. Not quite as long as some people would like it to be, but this question of slippage can be modified by alteration in the tread design. So that it is therefore quite possible that any experiment which took place two or three or more years ago would not now be very acceptable. That is all I have to say.

Chairman: Gentlemen, you will all join me in passing a hearty vote of thanks to Mr. Moss for his valuable paper.

We will now take up Paper No. 11 Although it stands in the name of Mr. Taylor, it will be introduced by Mr. Pennell.

The following paper was then submitted for discussion.

(*Paper No. 11.*)

NOTES ON THE PLANT USED FOR QUARRYING AND GRANULATING AND OPERATING COSTS ON THE GAUHATI-SHILLONG ROAD, KHASI AND JAINTIA HILLS DIVISION, ASSAM.

BY

B. F. Taylor R. N. Offg. Chief Engineer, Assam.

1. *General description.*—The quarry has been formed by excavating into a small hill one face of which is sold fine grained gneiss rock. The air compressor is situated well up the hill above the top of this rock face so as to be out of danger's way during blasting. For similar reasons the granulator is about a hundred yards away at the foot of the hill and screened by a small spur. A quarry road suitable for lorries running past the granulator and storage bins forms an arc to the main road which passes close by.

2. *Plant employed for quarrying.*—The following Sullivan machinery of the Sullivan Machinery Company, Chicago. (Sole agents for India—Macfarlane and Company, Limited, 18, Tangra Road, Entally, Calcutta.)

	Cost f. o. r. Calcutta.
	Rs.
Air Compressor, class WK312, size 6½ by 5¼	7,825
Drill steel furnace (oil), class G. F 2	1,000
Drill Sharpener, class C	2,375
Rotator hammer drills, class L7	500

It was found easier to get good tempering with an ordinary smith's tripod furnace using coke than with the oil furnace. When the furnace and sharpener are in use only one drill can be used and although when no sharpening work is being done it is possible to run two drills it has been found that better progress is maintained by running one drill only as with two drills running simultaneously full air pressure cannot be maintained with the result that the rotation speed of the drills drops with corresponding loss of efficiency. Also even when only one drill is working continuously the sharpener can only just about manage to keep it supplied with sharp and properly tempered drills since each drill only gives from 8 inches to 1 foot depth of hole before requiring re-sharpening and tempering. Three sizes of drills are used, *i.e.*, as the hole deepens its diameter diminishes, the larger drills give rather more penetration than the smaller ones before requiring re-sharpening but the above may be taken as the average penetration per drill. With this Compressor therefore it does not pay to use 2 drills.

3. *Plant employed for granulating.*—The granulator is a 12 inch by a 4 inch portable Hadfields complete with screen and loading platform. Costs f. o. r. Calcutta 5,350. (Sole agents for Hadfields, Limited, Sheffield :—Messrs. Balmer, Lawrie and Company, Limited, 103, Clive Street, Calcutta)

The standard dust excluder has not been found long enough as dust was still coming through with the small chips. It has therefore been lengthened by 15 inches allowing just enough room, 6 inches length of screen, for the small chips to fall out before the first line of 3/4 inch diameter holes for the large chips is reached. Changing the jaws and adjusting the clearance between them to alter the proportion of large to small chips produced is a very simple matter. The jaws both fixed and swing cost Rs. 50 each f. o. r. Calcutta. The teeth of the jaws are worn flat after producing 2,500 to 3,000 cft. of chips, when they have to be replaced.

The granulator is driven by an 18 B. H. P. Lister Diesel engine mounted on a trolley complete with cooling tank.

(Messrs. Balmer, Lawrie and Company are also the agents for these Lister engines.)

	Rs.
The prices, f. o. r. Calcutta, are—	
18 B. H. P. Lister engine	2,485
Trolley and cooling tank	152
The Fuel Oil used is supplied by the Digboi Oil Wells in Upper Assam, the cost ex-godown, Gauhati, being	97·12 per ton

The consumption is less than half a gallon per hour.

This engine was supplied without any air filter and considerable trouble was experienced due to dust, which is produced in clouds and forms an excellent abrasive, getting into the engine and wearing down the cylinder walls till air compression is lost.

After various trials a very satisfactory filter was evolved. The air intake pipe was lengthened some 20 feet and taken outside the engine shed, the end bent over at right angles and let into a 40 gallon drum with about 1 foot of old crankcase oil at the bottom, the mouth of the pipe being kept an inch or so above the surface of the oil. The air then enters through the bunghole at the top of the barrel, passes across the surface of the oil and so up into the air intake pipe. The barrel becomes full of oil fumes sufficiently thick to catch the dust which falls into the oil and so is trapped and prevented from continuing to circulate in the air. This is the general principle of the air filters on the Caterpillar tractors and is most efficient.

The engine should be sited up wind of the granulator and the driving belt be sufficiently long to keep it 20 feet or so away. When both the granulator and the engine are working under cover, the granulator shed should have open sides, or the dust becomes suffocating. The engine shed should have walls, a dust proof wall with a small opening only for the belt drive being essential between the engine and the granulator. These engines are provided with cylinder liners but they are expensive and it is worth while going to some trouble to keep the engine room as free of dust as possible.

4. *Outturn.*—Each rotator hammer drill gives 25 to 50 feet of hole per 8 hour working day according to the hardness of the rock.

The granulator produces on an average 300 cft. of chips per 8 hour day but has been worked up to 500 cft.

5. *Blasting.*—The charges are fired electrically, some 6 to 8 holes being exploded simultaneously. The depth of each hole is 2 to 2½ feet and 1½ to 2 cartridges (10 cartridges to the pound) of dynamite are found sufficient per hole. Holes of greater depth produce too large pieces of rock which are difficult to break to a section of less than 12 inches by 4 inches the size of the granulator jaw opening. Holes two feet deep spaced fairly close together so as to shatter the rock were found most economical.

Dynamite proved much more successful than gelignite as the latter did not shatter the rock sufficiently. Blasting gelatine would probably give still better shattering results but is considered too unsafe for use by unskilled labour.

6. *Costs.*—With labour rates as noted below the following are the cost :—

Compressor driver who also sharpens and tempers the drills	Rs. 45 per mensem
Handyman	Rs. 25 per mensem.
Lister engine driver	Rs. 35 per mensem.
Handyman	Rs. 26 per mensem.
Head driller	Rs. 1·4 per day.
Assistant driller	As. 12 per day.
Cooly, male	As. 8 per day.
Cooly, women	As. 6 per day.
Cooly, boys	As. 4 to 6 per day.

Analysis of rates for 100 cft. of granulated fine grained gneiss chips from Basbari quarry in mile 34/5 of the Gauhati-Shillong Road including quarrying large stone.

	Rs.	a.	p.
1. Cost of running the Compressor for 100 cft. of large stone	4	6	0
2. Cost of drilling	0	7	10
3. Cost of blasting	2	7	8
4. Cost of clearing and breaking to size	1	15	0
5. Cost of carriage of large stone to granulating shed	1	0	5
Total quarrying costs per 100 cft. of large stone of section not exceeding 10 inches by 4 inches	10	4	11

For 100 cft. of granulated chips 125 cft. of large stone are required :—

	Rs.	a.	p.
Cost of 125 cft. of large stone at Rs. 10-4-11	12	12	3
Allowance of 5 per cent. on Rs. 12-12-3 for unserviceable stone obtained by blasting	0	10	2
Cost of granulating 100 cft. of chips	5	12	0
Cost of carriage to storage bins and boxing 100 cft. of chips	0	12	10
Total	19	15	3
Say Rs.	20		

DISCUSSION ON PAPER No. 11.

Mr. K. E. L. Pennell (on behalf of the author): Mr. Chairman and gentlemen, I have not got anything to add to what is given in this paper except to say that the reason why we had to adopt granulators was because we found that the cost of breaking chips by hand labour became absolutely exorbitant. We were using the hardest stone we have in Assam and we had great difficulty in getting the coolies to break it even to road metal size, one inch to 2·5 inches, when ordered to break it to ¾ths of an inch they found it practically impossible and refused to face the job at all. So the only thing to do was to instal granulators and we found the cost was certainly very much less than we would have had to pay for hand-breaking and even slightly less than we had been paying for hand-breaking to road making size.

Mr. A. W. H. Dean: I would ask whether any trouble was experienced from excess of elongated chips from this process. Were the chips of a cubical shape?

Mr. K. E. L. Pennell: No, we found that with the granulator the chips were more cubical than the debris in the quarries where they had been hand-breaking to ordinary road metal size. Previous to getting the granulators we had used the debris in the ordinary quarries by screening it for chips and these hand-broken chips were definitely wedge-shaped and very elongated. We have a Hadfield's granulator, the swing jaw on which is on an eccentric shaft; so that in addition to the horizontal motion there is also a vertical motion and consequently the resulting motion of the swing jaw is a slightly rolling one, and it produces nicely graded cubical chips, which do not contain any elongated pieces.

A member: Mr. Chairman, I have also to ask one or two questions because we have also crushers and we have experienced the same kind of nuisance about which mention has been made in the paper. One of our crushers was installed very close to the ground and the stuff was falling into the pit and the nuisance was very great. So when we wanted to instal another crusher we reduced it to a certain extent in order to protect the men from these respirators because they find them very difficult to work. I should like to know whether any attempt has been made to solve this dust nuisance. We have got a semi-portable steel boiler, so that the trouble about asking the people does not arise. The trouble is about the people who work there. Similarly, we have got quarries in the same vicinity and we find that in one case we get a hard stone and in another case a soft stone. While in the case of the soft material the change is affected after an output of 45,000 feet. Our cost of crushing works out to about Rs. 4-4-0 per cubic foot.

Mr. K. E. L. Pennell: The only other question which has been asked is how we are dealing with the dust nuisance. Frankly we don't know. The only thing we can do is to have a shade over this granulator without any walls. We first of all provided walls with the result that the men were absolutely suffocated, so we took the walls down and raised the roof rather higher to get some breeze through it, and the men had to get on as best as they could. I do not see how we are going to overcome the

dust nuisance at all except by so sitting the granulator that the prevalent winds operate in the same way as described whereby the engine is upwinds of the granulator. (Loud Applause).

Chairman: I think all will join me in passing a hearty vote of thanks to Mr. Taylor, the author of this paper, and to Mr. Pennell for having kindly answered the questions raised. (Loud Applause).

I think we will leave the concrete papers for to-morrow morning. Will Mr. Meares kindly come up and introduce his paper?

Mr. H. A. Hyde, M.C., Chief Engineer, P. W. D., Central Provinces, took the Chair at this stage and the following paper was then submitted for discussion.

(*Paper No. 13.*)

TEST TRACKS—A SUGGESTION.

BY

C. D. N. Meares (Standard-Vacuum Oil Company.)

The object of this paper is not to give any startling information but rather to offer a suggestion which, should it meet with general approval and support, will, I feel sure, lead to a very definite advance in the science of Road Construction in India.

2. In brief, the suggestion is that we have in India now reached a stage where independent experiment with different road building materials and specifications should be discouraged in favour of the establishment of a central Road Authority, or Authorities, who would undertake any research necessary under the most economical and favourable conditions. There are two aspects to every road problem: the theoretical or laboratory side, and the practical or service side. For maximum efficiency it is necessary to provide facilities to study both. The theoretical or laboratory side requires no enlargement, but the practical side is quite a different matter, and calls for considerable outlay if experiments are to be undertaken by each and every local authority on actual sections of road which are proposed for treatment. Apart from this, however, the greatest objection is as regards time—it takes years to get results and during the course of these years most of the personnel have changed, records are lost or no longer maintained on the original lines, so that the experiment has little ultimate value. The ideal condition would therefore be to reduce the practical or service side also to a laboratory problem in which all the factors to be considered can be reproduced on an economical scale and under exact control. This ideal brings me to the subject of this Paper, Test Tracks.

3. A Test Track is simply a road surface laid precisely as other surfaces under working conditions, but carrying exactly controlled and intensified traffic, so that the life of any particular specification or material can be rapidly measured and co-related with existing data to give a substantially accurate estimate of what that particular specification or material will do in practice. In this connection, a brief description of the Test Track constructed by the Dutch East Indian Road Association at Bandoeng, Dutch East Indies, will be of interest.

4. *The Test Track at Bandoeng.*—The Track is an oval with straight sides each 135′ long, connected with ends in the shape of semi-circles of 50′ radius, giving a total length of approximately 600′. The paved width is 15′, and on either berm there is a rail mounted on concrete supports to act as a guide rail for the vehicles. Traffic is restricted to two vehicles, one a synthetic motor lorry running at 14-16 m. p. h: and the other a synthetic bullock cart running at 3 m. p. h., both of which are electrically driven and take power from overhead wires. The running of the vehicles is controlled from a main switchboard and they are guided automatically by being connected to the guide rails. The bullock cart is connected with the inside guide rail and the lorry with the outside rail, while the connections are telescoping, so that the wheels travel over a comparatively broad area instead of exactly tracking. Each vehicle is a 3-wheeler, the lorry

having the drive transmitted through a differential to the rear wheels thus reproducing actual conditions, while the bullock cart has the drive concentrated in the third rubber tyred wheel in front to give the effect of animal traction. In each case, the third single wheel is the steering wheel and the telescopic action of the connector arm to the guide rail is automatic through an eccentric. On each vehicle, the rear wheels only are the test wheels and weight on the front wheel is limited to a minimum. The paved portion of the track has a 10′ boulder foundation, this being preferred to concrete as more nearly approaching actual conditions. Over the foundation is a 2½″ course of waterbound macadam, and the material or specification to be tested is laid on top of this macadam.

The five Photographs appended to this Paper will help to clarify the foregoing brief description.

5. *Operation.*—The method of operation is to divide the track into 4 sections, each containing half the length of one straight and half the adjoining curve. Thus four separate and distinct trials can be carried out simultaneously under precisely similar conditions. The vehicles are started, and an automatic counter records the number of revolutions of each. Photographs are taken at frequent intervals, and careful records kept of the condition of each strip as the test progresses. In order to get even more accurate data a Profilo-meter which records the profile of the track at different stages was also tried, but this has not proved entirely effective.

6. *Costs and Finance.*—The total cost of the track, inclusive of vehicles, was in the neighbourhood of 35,000 Guilders—about Rs. 52,000 at the present rate of exchange—a not unreasonable figure. This outlay was met from the funds of the D. E. I. Road Association which in turn is financed by grants from Government and Local Authorities. The first tests carried out on the track were all undertaken at the expense of the Association, but since then it has become the rule for firms dealing in Road Materials to donate the quantity required for any tests they advocate, other costs being borne by the Association. The present procedure is to undertake tests at the instance of any Road Authority or approved suppliers, the cost thus being divided between the Association and the supplier in the latter instance. It is considered that no firm of repute is likely to ask for tests unless they are reasonably sure of themselves, and in such cases the Government also benefits by the data obtained and thus the arrangement is equitable to both parties. Information regarding successful tests is disseminated regularly among subscribers to the Association, and it cannot be too strongly stressed that in this direction lies the true value of a centralised Test Track.

7. *Adaptation to Indian Conditions.*—Far be it from me to criticise the Bandoeng Track, but failing an opportunity to discuss the matter with the Dutch East Indies Road Association authorities, it seems that there are several possible improvements and economies. Commenting with due diffidence—

(1) It would appear that an improvement would be to have one wheel of each vehicle running in the same track (I will enlarge on this subject later). Experience in India leads me to believe that most of the damage to unsurfaced roads is done by the

combination of fast-moving rubber-tyred traffic and destructive steel-tyred traffic, while in many cases the rubber-tyred traffic has actually a beneficial effect on paved roads carrying bullock cart traffic also.

(2) The average speed of Motor Buses nowadays is nearer 30 m. p. h. than 14-16 m. p. h.

(3) Tests could be very much accelerated by using a train of bullock carts towed one behind the other.

(4) A better measure of information would be obtained by varying the radii of curves.

(5) A central Test Track may be quite sufficient in the Dutch East Indies for the good reason that the stone available throughout the Islands is uniform, and the climate ditto. In India we would have to have several such tracks to cope with wide variations in climate and material.

8. This last item brings us to a slight impasse. The objection to any accelerated test is that we are quite unable to reproduce the time factor which is important in that it may have a very considerable bearing on the behaviour of a particular road binder under service conditions. Also we cannot reproduce variations in temperature—another important factor. The latter can be overcome to a certain extent by carrying out the test of any particular specification at the season of year known to be most inimical to its success while the effect of rain can be reproduced by means of a common or garden hose. I believe, however, that these objections can well be taken care of by co-relation of known results with those obtained on the Test Track.

9. However, taking the five criticisms enumerated above into consideration, I would offer

A Suggestion.

This is only a suggestion, but it is submitted for your earnest consideration in the firm belief that developments on the lines indicated will be a very real step forward in the history of Indian Road Construction. My suggestion is not one suggestion—it is a series of suggestions, each representing a definite stage in the attainment of a final ideal.

10. *1st Stage*: Establish a properly equipped laboratory in Delhi for the examination and test of aggregates, binders and samples taken from actual roads, both successful and unsuccessful.. This lamoratory to be erected solely for road research.

Establish a Test Track in Delhi, in itself experimental, to determine a cheap and efficient type.

Conduct a series of experiments to co-relate Test Track results with known results of various materials and specifications.

11. I have suggested DELHI as being a central point for India and also because the P. W. D. of that province have already a wealth of information available which could very easily be related to results obtained on the Test Track Moreover, if these suggestions are ever adopted the Road Institute or Board or Association or whatever you like to call it must have a headquarters somewhere, and where better than in DELHI,

where, presumably, further Road Congresses will assemble annually. For this first stage, I would suggest earmarking Rs. 1 lakh to include the cost of Tests of all standard specifications now being used in Delhi.

12. *2nd Stage*: Establish similar Test Tracks in centres most representative of climatic conditions over the area they will serve, and to which cartage of aggregates, etc., from outlying districts would be convenient.

You will notice that I do not suggest the establishment of further Laboratories. One central Laboratory should be ample for India, firstly, as the conveyance of samples, etc., is cheap and, secondly, because a really well trained Chemist would be an expensive item of the yearly budget.

13. *An Indian Test Track.*—I am not going to attempt to design a track myself, but would outline an idea that might be worth development. Again, taking the five points mentioned before as accepted modifications:—

(1) Have the actual Test Track 8′ wide—the soling and metalling to be 10′, say 600′ long or approx. 5,000 sq. ft. of testing area. Have two corners of 25′ radius and two of 50′ radius.

(2) Use light rails mounted on concrete pillars as Guide rails, spaced say 12′ apart.

(3) Construct a light 4-wheeled trolly to run on these rails (Gauge 12′) carrying an electric motor of sufficient power—say 10 h. p. to propel the back half of a lorry at 20-25 m. p. h.

(4) Mount the motor (which will take power from an overhead wire) on a platform free to slide transversely on the trolly platform. Connect this platform through a link and eccentric to the trolly wheels so that the whole platform slides 18″ say, every 20′ of forward motion.

(5) Connect to the platform carrying the 10 h. p. motor, the back end of a lorry chassis, with a drive from the electric motor through the gear box to the carden shaft.

(6) Fix a connection for the bullock cart or carts on the lorry so that it or they can be towed behind with one wheel running in the track of the lorry wheel. If bullock carts of 2′ 4″ track are used (allowing a 4′ 8″ track for the lorry), the other wheel can ride in between the tracks made by the lorry wheels.

(7) The bullock carts can be made easily detachable so that they can be removed and man-handled off the track when the lorry test is in progress.

(8) To accelerate tests it may be desirable to have two or more bullock carts suitably loaded and towed one behind the other to approximate the unfortunate condition we all know too well in India.

14. The operation of a Track on the above lines would be simplicity itself and the initial cost low. In action, the lorry would be on the track all the time, running for part of the time, in top gear as a lorry proper at 20-25 m. p. h. without the bullock carts, and at other times, running in bottom gear at 3 m. p. h. acting merely as the tractive force for the train of bullock carts. A suitable factor could be introduced to relate

the number of revolutions of the lorry in the latter case to its number of revolutions as a lorry proper. From a Test Track on these lines, three separate and distinct results would be obtained:—

(1) Of lorry traffic alone, as on roads, where carts stick to the sides and fast moving traffic holds the middle;

(2) Of mixed lorry and bullock cart traffic, as on roads where traffic is distributed over the entire width;

(3) Of bullock cart traffic under conditions, such as (1), showing what would happen to the sides of the road.

15. The application is obvious. It may be found that a comparatively cheap specification could be used on the centre of the road and a more expensive for the sides. Even more exact data could be obtained by considering direction and load in the traffic census. Let us consider an actual example of working the Test Track in which it is desired to compare the respective merits of 3 or 4 different specifications on the approach road to a town. Assume the following data:—

Width of road	12′
Bullock carts	300 per day.
Lorries	100 per day.
Cars	80 per day.

Test track carries a train of 3 bullock carts.

Two cars equal one lorry.

16. The specifications to be tested would be completed under the most careful supervision on the Test Track, and the test run continuously. The relation between bullock carts and lorries is as 3: 1·4, but since we have a train of 3 bullock carts, the number of revolutions is reduced to the proportion of 1: 1·4, or, in other words, our bullock cart train must run 1,000 revolutions to every 1,400 of the lorry proper. You will note that in the example I am omitting to take into consideration the revolutions of the lorry while proceeding at 3 m. p. h., as I very much doubt if this factor need be included at all.

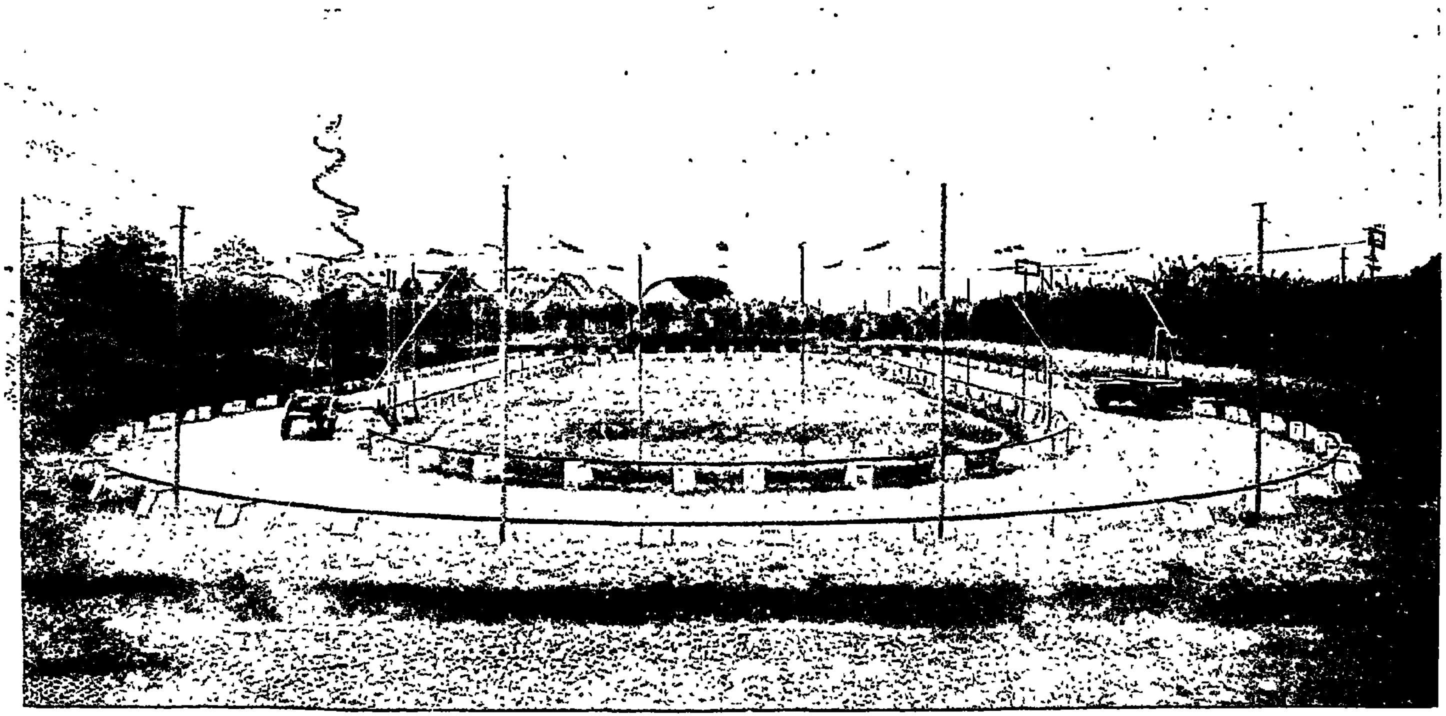
17. Now the bullock cart train runs at approximately 3 m. p. h., or say, 27 revolutions per hour, while our lorry runs at 20-25 m. p. h., or say, 200 revolutions per hour. A typical start of the test would be to run the lorry for one hour and the bullock cart train for 5 hours. Slight adjustments in this schedule would be necessary as the test proceeds to keep the relationship constant. Let us assume that the tracks made measure an average of 2′ in width, and that for any particular specification we get the following results:—

(1) The cart track requires maintenance first at 10,000 revolutions of the cart (during which time the lorry has done 14,000 revolutions);

(2) The lorry-*cum*-cart track requires maintenance at 15,000 revolutions of the cart and 21,000 of the lorry;

(3) The lorry track is intact at the end of this period.

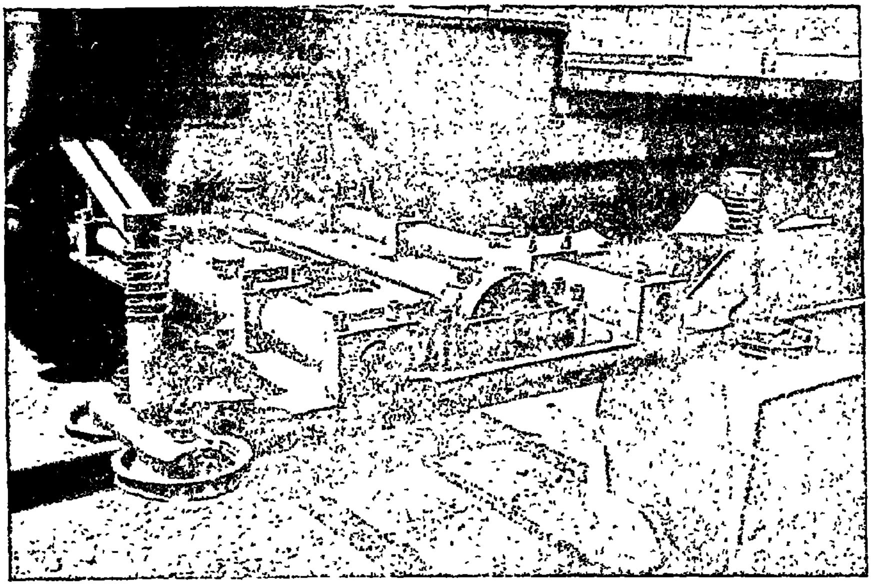
18. To interpret these results it is easy to calculate that in the case of (1), an actual road will require maintenance for the bullock cart track at the end of 100 days if the carts track one [illegible]d the other. Of course,



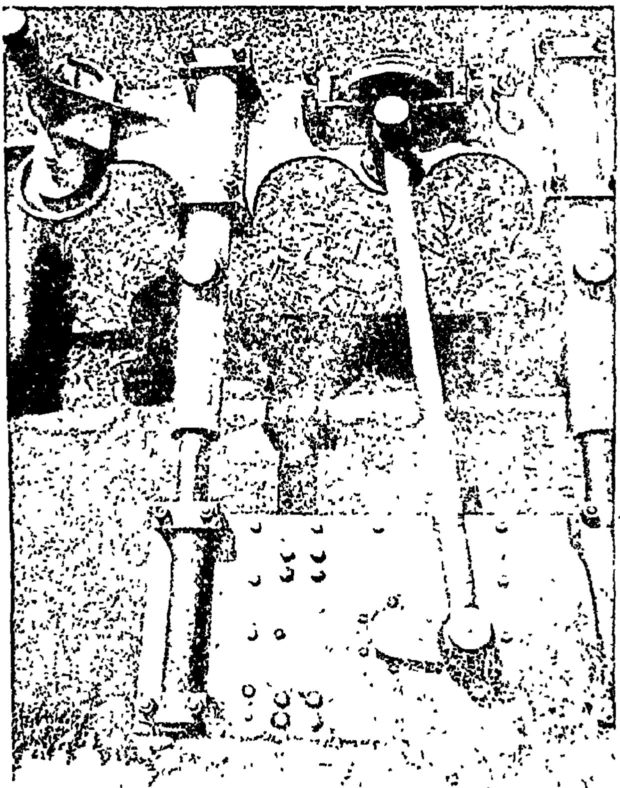
No. 1.

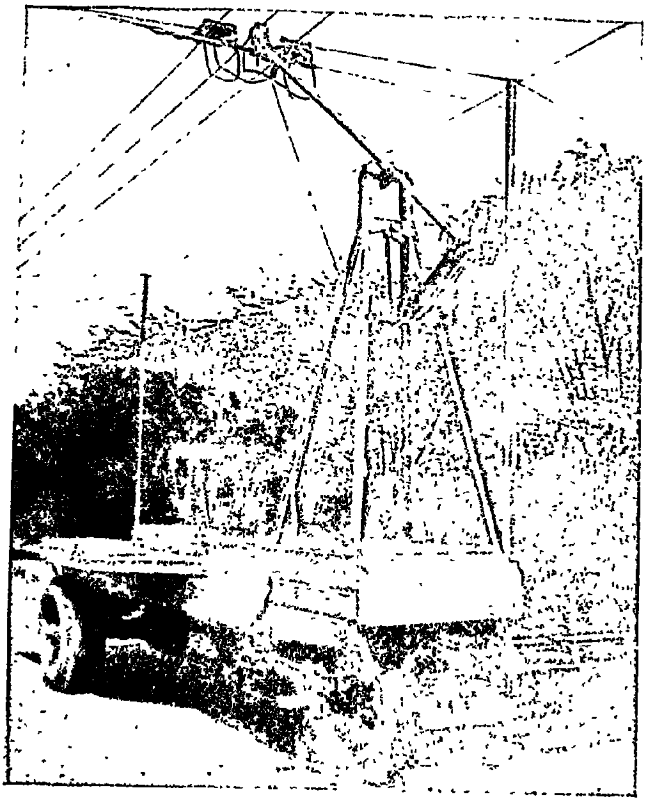
GENERAL LAYOUT OF THE BANDOENG TEST TRACK SHOWING THE BULLOCK CART ON THE LEFT AND THE LORRY ON THE RIGHT.

Reproduced by Courtesy of the N. E. I. Road Association.

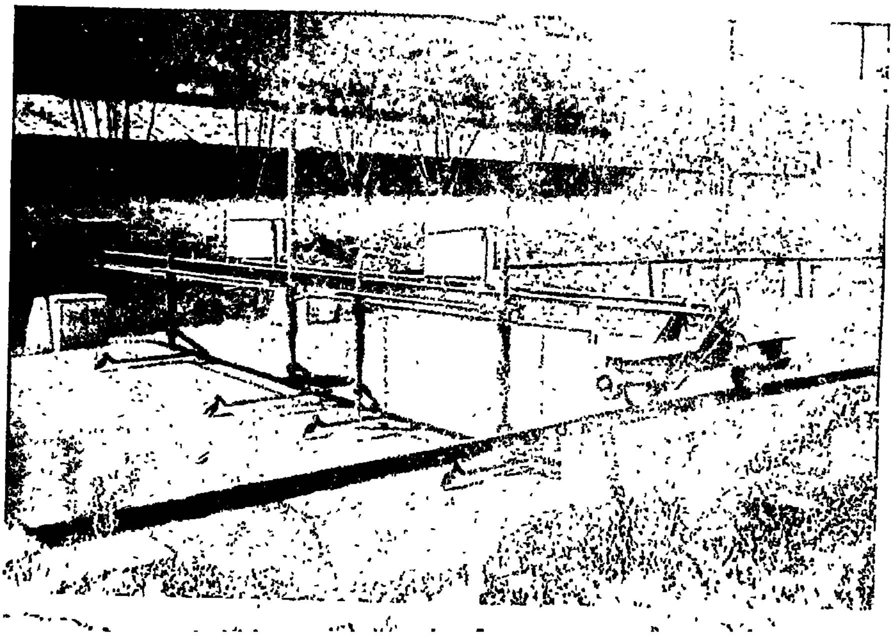


NO. 2.
DETAILS OF THE AUTOMATIC TELESCOPIC CONNECTOR ARM FROM GUIDE RAILS TO VEHICLES.





No. 4.
THE LORRY.



this expectation of life must be amended by any factor found necessary between actual and test track results, *vide* my mention of co-relative tests.

19. If bullock carts are distributed over the whole width of the road, however, and their tracks mix with the lorry tracks, we have result (2), but distributed *over 12′* instead of 2′, so that the expectation of life without maintenance is 6×150 days $=900$ days. We know also, that if the carts track one behind the other, probably on one side as is frequently the case, we can expect the rest of the road to stand up without maintenance for 900 days, but that the sides will have to be constantly repaired. From the information we may find that it would be more economical to use a heavier specification, or, possibly, widen the road to 18′ and put in a heavier specification track 6′ wide on one side for bullock carts going into the town heavily loaded. Anyway, the point is that data of this kind would be a very real help to any Engineer engaged in the designing of roads.

20. It is hardly necessary to mention that the possibilities are enormous. A test such as that described would take only a little over a month, cost say Rs. 5,000, and might well be the means of saving ten times that sum. Carried to its logical conclusion, I can envisage a scheme such as that briefly outlined will, in the course of a few years, reduce Road Construction to very nearly an exact science. Charts can be prepared for different localities, aggregates and specifications in which percentages of carts to lorries are plotted against the expectation of life with and without maintenance per 100 vehicles per foot in width for different conditions of traffic.

DISCUSSION ON PAPER No. 13.

Mr. C. D. N. Meares (the Author): Mr. Chairman and gentlemen. I have very little more to add to this paper but I would like to take this opportunity to thank those of you who have written or spoken to me offering suggestions. One suggestion is that the track as envisaged is too big. I pointed out in the paper somewhere that four tests are carried out simultaneously, and I think you will agree that with a six hundred feet track and only 150 ft. for each test, it is not excessive. Another suggestion was that we should introduce gradients on the track. I do not think that is very feasible. (Applause).

Chairman (Mr. H. A. Hyde, M.C.): Does any member wish to ask any question in connection with this paper or to offer any remarks?

I should like to say myself that I think this idea of an experimental track might be of the greatest value and I think in connection with the Roads Congress a central experimenting station including a track of this nature should be seriously considered. As I think Mr. Mitchell suggested, we would exchange results of experiments and experiences; nearly everybody has made experiments with various types of roads, and if some of this experimenting were centralized, it might have the effect of saving a great deal of money. An experimental station for practical tests and a laboratory attached should I think be seriously considered by the Road Congress. Has Mr. Mitchell got any views on an experimental station of that nature to be started and financed from the Road Fund, instead of, as has been happening, giving out a certain amount of money to the Provinces for purposes of experiment? Has anybody got any ideas on this point?

Mr. A. W. H. Dean: One thing about the experimental work done in Delhi is that we saw things that had not been tested. If we had a test track, then definite figures would be of value.

A Member: Is it proposed to introduce more than one test track?

Mr. O. H. Teulon: It seems desirable to have one for a dry country and one for a wet country where the humidity and high temperature can rapidly disintegrate most things including road surfacing materials. We should therefore take into consideration the question of materials for use in earth roads.

Chairman: That is an obvious disadvantage to having a test track: one test track could not very well introduce the climatic factor; but even so, I should imagine that if a test track in Delhi for instance were used during the rains, during the hot weather or during the cold weather, one could obtain certain amount of variation even in a central place but not quite to the same extent as might be desirable.

Mr. C. D. N. Meares (the Author): The suggestion I had in my mind was that the first test track should be in Delhi so that we might get some idea from that as to the type and its usefulness and so on, and later on, if we find that there is money available, to establish one for each Province. That answers Mr. Teulon's question I think.

Mr. G. Reid Shaw: I think this is a most excellent idea if it is going to be done properly. If we are going to have a proper test track and laboratory, the work must be done properly and this will necessitate the co-operation of the chemist and physicist as well as engineer. It would

be no good telling us what the results are at Delhi unless an absolutely correct definition of the stone and the condition under which it is used are given.

Mr. C. D. N. Meares (the Author): I suggested, I think in connection with the test track, a central testing station and a laboratory for testing material as well.

Mr. G. Reid Shaw: If we can have that, of course it would be most useful.

Mr. D. Macfarlane: Might I suggest for what it is worth that if this test track is going to be run at all with or without a testing laboratory and chemists, it is essentially a thing that must be centralized by the Government of India. We would not get anywhere if we merely discussed amongst ourselves what an excellent thing it would be and then we left it at that and hoped for the best. I would suggest to Mr. Mitchell not as Secretary of this Congress but as the Consulting Engineer (Roads) that this Congress might pass a formal resolution that we should recommend to the Government of India that they themselves should start a research bureau more or less on the same lines as is I think done in the case of irrigation research. I do suggest for what it is worth that if we do pass a formal resolution, something might possibly come out of it. (Loud Applause.)

Mr. K. G. Mitchell: Mr. Chairman, I think we ought to be very grateful to Mr. Meares for bringing this to notice particularly at this juncture because we are now possibly in a position to go ahead with it. If this Congress is to come into being as we now all hope it will be and if it is to have committees for promoting research and intelligence, it will be possible for us to do a great deal in this way under your direction and advice. So long as we were somewhat isolated and had to correspond with each other through purely official agencies, that was not easy. The congress met this morning and amongst other things proposed is to appoint a technical committee to consider that are the most urgent questions which will have to be taken up, to recommend on what subjects papers might be read at the next Congress, and generally to advise on future research and intelligence. Here you have proposals on the one hand and, on the other hand, you have a body which is eminently qualified to deal with them. My own ideas are nebulous at present, but I have had it in my mind for some time that, with the transfer of the agricultural research station from Pusa to Delhi, which is perhaps not very popular everywhere, it does give us an opportunity of having scientists here on the spot and possibly there is plenty of room and we can combine this test track with them and have a road research station in conjunction with the agricultural research station and you can see all the scientists who will be on that station and who will be of very great assistance to us in connection with a vast range of subjects including soils or earth roads and so on. I think if the congress will now pass a resolution saying that they consider it desirable that some kind of central research station including a test track and other equipment should be set up, it ought to be possible to do it in conjunction with the agricultural research station and I think that that will be a very suitable arrangement. As regards the Provinces subscribing, possibly that would not be necessary at this stage because, as you know, the reserve in the Road Account was created *inter alia* to provide funds for research and experiment and

I cannot conceive that that money could be better applied than in having a research station if it is not too expensive and to carry out a programme of research directed by the advice of this Congress. (Loud Applause).

Mr. D. Macfarlane: If I understand Mr. Mitchell correctly, it means that his hand would be strengthened if a Resolution to this effect is passed at this Congress.

Mr. K. G. Mitchell then proposed the following resolution:

"This Congress recommends to the Government of India that a Central Road Research Station including a test tract should be set up in Delhi and be financed from the Central Reserve in the Road Account. The details and an estimate of the initial and recurring cost to be worked out by a technical sub-committee of the Congress".

Mr. D. Macfarlane: I think we can get the sub-committee of the Congress to work out the details to-day. We should merely put forward the form of the resolution and leave it to Government to find the money.

Mr. K. G. Mitchell: We have appointed a technical sub-committee of the congress and it seems to me that it is rather for that body to advise us how far we can go.

Mr. D. Macfarlane: I thoroughly agree with you on that point but I rather doubt their capacity to do so. You, as Secretary of the Congress, are in a better position to do this.

Mr. S. S. Bhagat: We might indicate on what lines we want this track to be constructed. We might say about the different materials and also the different traffic conditions. All these points should be brought to their notice when they consider the construction of this track.

Mr. K. G. Mitchell: It will all have to be gone into very carefully and that is the reason why I wish to get the assistance of the technical sub-committee.

Mr. S. S. Bhagat: That is exactly my point. The sub-committee would probably be more able to help on those points and then the Government of India can get on to the job.

Mr. K. G. Mitchell: This is a matter of great importance. Actually the Provisional Committee this morning has appointed a sub-committee which consists largely of people who are not too far from Delhi so that they can meet fairly easily. It will not be a question of postponing it. We had better leave the Resolution like this:

"This Congress recommends to the Government of India that a Central Road Research Station including a test track should be set up in Delhi and be financed from the Central Reserve in the Road Account."

Mr. D. Macfarlane: We had better not throw cold water on the efforts of the sub-committee. If they can get down to any concrete proposals so much the better. A speaker said this morning that he did not quite see where this Congress was getting at. Here is an opportunity of getting at something definite and concrete.

The Chairman put the Resolution which was passed with acclamation.

Mr. K. G. Mitchell: We would like to discuss the constitution of the future Committee at half past two to-morrow and we shall then finish.

The Congress then adjourned till 10 A.M. on Thursday, the 13th December 1934.

Fourth Day: Thursday, December 13th, 1934.

The Congress reassembled at 10 A.M., Mr. O. H. Teulon, Chief Engineer, Public Works Department, Burma, in the Chair.

Chairman: Gentlemen, it has been decided to take up papers Nos. 7, 8 and 9 together. I would therefore ask Mr. Greening kindly to introduce his paper No. 7.

The following paper was then submitted for discussion.

(*Paper No. 7.*)

THE USE OF CEMENT FOR THE CONSTRUCTION OF ROADS IN THE BOMBAY PRESIDENCY

BY

L. E. Greening, Executive Engineer, Bombay.

1. The advantages of cement as a material in the construction of roads has been recognized by the Public Works Department of the Bombay Presidency, but its use has been, by reason of financial stringency, restricted, and as a result such construction is largely in the experimental stage. The roads of the Bombay Presidency in the charge of the Public Works Department are for the most part in open country, connecting one large town with another, passing through scattered villages only. The portions through the large towns and the subsidiary roads therein do not normally come within the province of the Public Works Department, but within that of the Municipalities concerned.

2. In 1930, an experimental length of cement macadam road was constructed on the Poona-Nasik Road in the Nasik Division. The method of construction was the "Sandwich" method in which a layer of trap road metal was first laid loosely to a depth of 2¼ inches, true to longitudinal grade and camber, and lightly consolidated by means of a road roller of 10 tons weight. Upon this initial layer of road metal, dry mortar consisting of one part of cement to two parts of sand by measurement, was laid to a depth of 1½ inches. Over this a final layer of road metal was then laid to a depth of 2¼ inches, after which the surface was lightly watered at a rate of approximately 35 to 50 gallons of water per 100 square feet, the quantity varying with the atmospheric temperature at the time of application. The surface was then consolidated with a road roller, until the mortar appeared on the surface, having filled the voids in the road metal, so as to form a homogeneous material. On the completion of the rolling, the surface was lightly tamped by means of a heavy wooden screed in order to remove any inequalities, and then cured under water for a period of 14 days, after which a further period of 7 days was allowed to elapse before the road was opened to traffic. This type of construction cannot be said, however, to have been a success. Soon after completion several longitudinal and transverse cracks made their appearance and had to be treated with hot bitumen. Later, the surface commenced to disintegrate in places, where presumably the mortar had not permeated thoroughly the layers of road metal. No expansion joints were at first provided but later these were found to be necessary and were provided as a means of prevention of transverse cracks. Considerable trouble was encountered at the joints because the roller could not be used for consolidation in their immediate vicinity and thus this important function had of necessity to be performed by means of hand rammers. A possible solution of this difficulty lies in the formation in advance of cement concrete bars

of say 9 inches in width at those distances at which joints were to occcur, and to allow them to set sufficiently hard to carry a road roller across them. The cost of the cement macadam roadway in question amounted to Rs. 2-9-0 for one square yard of finished surface, for which area the quantity of cement used was approximately 50 lbs.

3. For the purpose of comparison a true cement concerete roadway was laid on the same road in 1931. This consisted of three widths each of nine feet, the total width of roadway thus being 27 feet. The section of each width or slab was of the dimensions 6 inches at the edges, reducing to 4 inches for the central two feet, and each slab was laid in lengths of 35 feet, quite independently, on the strip method. Transverse joints were provided, a premoulded bitumen filler of 3/8 inch thickness being used for this purpose. No longitudinal joints were used, each concrete strip butting against the other. The roadway, the cost of which was Rs. 5-5-0 per square yard, has been so far entirely successful. The proportions of the concrete were 1 : 2 : 3 and gave, on test, an average crushing strength at the age of 28 days of 440 tons per square foot.

4. Early in 1933, on the Poona-Ahmednagar Road in the Poona Division a short length of roadway was laid composed of side widths of cement concrete 6 feet wide and 6 inches thick, and a central width of 7 feet 6 inches of bituminous (grouted) macadam. The object was to provide a cement concrete track on each side for slow moving bullock cart traffic, and a central width for the passage of fast moving traffic. Owing to the short length of time during which the road has been subjected to actual traffic conditions, no definite opinion can as yet be given as to the degree of success attained. The cement concrete side strips had a uniform thickness of six inches, and were laid in lengths of 40 feet. Expansion joints of the pre-moulded bitumen type were provided and also three steel dowel rods were inserted at the joints each having a length of 4 feet and a diameter of ¾ inches.

5. In the three types of roadway described, the cement used was manufactured in India, and complied in all respects even the requirements of the British Standard Specification.

6. There are, it is considered, two factors tending to militate against the more general use of cement in road construction in the Bombay Presidency, the one, being its comparatively high initial cost, and the other, the essential need of construction by somewhat highly skilled labour. As regards the first, the present unfortunate financial position operates adversely and in the second case, the labour which has of necessity to be employed is of a low order, requiring constant and detailed supervision. Further, the volume of traffic other than in towns and large villages is not such as to warrant such comparatively costly construction.

The problem of the slippery surface has not so far arisen to such an extent as in other countries due possibly to climate and to absence of intense traffic conditions, certainly no complaints on this score have so far been made by users of the highways of the Bombay Presidency.

Mr. L. E. Greening (the Author): Mr. Chairman and gentlemen, I have very little to add to my short description of the use of cement in road construction in the Bombay President. Two types of construction were employed that is cement macadam and cement concrete. The cement macadam was laid for a length of one mile and was not a success. In this respect, I might mention that a similar length was laid shortly afterwards in the Poona division. They no doubt profited by the length we laid down originally and this has shown far better results. The length of true cement concrete has been, so far as I am aware since I left the Nasik division in 1931, entirely successful. The second length of true cement concrete referred to in the paper now before you follows generally a similar type of construction to that of a trackway or crete way in the Lyallpur district which we were recently privileged to inspect. In this case, however, the concrete strips were of a width of 6 feet and were laid directly on to the original water bound macadam road after it had been resectioned, such resectioning being necessary to ensure that the concrete strips had a uniform bearing which I might emphasise as being an essential factor in concrete road construction. The central portion between the concrete strips was laid in asphalt grouted macadam. That is all I have to say.

Chairman: Will Mr. Turnbull please introduce his paper No. 8.

The following paper was submitted for discussion.

(*Paper No. 8.*)

CEMENT CONCRETE ROADS

BY

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(The Concrete Association of India.)

Owing to the urgency of the demand for roads to meet existing traffic requirements, research has lagged behind construction, and many concrete roads have been laid without a full knowledge of the many factors affecting the design. However to-day we can say that our knowledge of these factors has reached the stage when we can design with assurance a road which will meet the exigencies of modern traffic at least.

2. As in every other problem of structural design, the designing of a concrete road resolves itself into first, a decision as to the forces which will act on it, and second an economical design of a concrete slab that will resist these forces. With our present knowledge of concrete, the second is fairly straight forward. The first, or estimation of the forces which will act on the road, is much more difficult, and this difficulty is due to the lack of uniformity in the sub-grade.

The subgrade.

3. The subgrade may be defined as the natural foundation upon which the concrete slab and its loads are carried, as for example, virgin soil. A base on the other hand is an artificial foundation such as an old water-bound macadam road. To design a concrete road slab economically we must assume that it is supported to a certain extent by the subgrade or base. By experience we know that the character and condition of the subgrade affects the behaviour of any type of road surface, and thus it can be seen that a knowledge of the properties of the materials which comprise the subgrade is of vital importance. A great deal of research has been carried out recently on subgrade materials, and engineers can now make a more intelligent estimate of the foundation conditions for the concrete road slab which they propose to construct.

4. One of the most important characteristics of all subgrade materials is the tendency to change in volume under a change in moisture condition. Certain clays may change as much as 50 per cent or more. Sandy soils change least of all. Moisture conditions under a concrete road slab are not uniform, the moisture content near the edge is usually different from that in the centre. It can thus be seen that with a soil whose volume change is large there will be uneven support and probably no support at all under the edges of the slab. It is desirable therefore to have as a subgrade a material whose volume change is small.

5. If subgrade materials can be kept relatively dry little trouble will be experienced; those soils which are difficult to drain represent one of the main problems of the Road Engineer. It is the moisture in the soil

immediately under the concrete slab which concerns us most, and this moisture may enter the subgrade in many ways such as:—

1. Surface water which is not properly cared for and slips in through the cracks and joints of the concrete slab and around the edges.
2. Capillary action of the material itself which is continually drawing in moisture from the surrounding soil.
3. Porous strata often exist which periodically become water bearing and carry water into the subgrade, and if no exit is provided it collects and a bad subgrade condition results.

With a subgrade which decreases in stability as the moisture increases precautions must be taken to keep the moisture content low or if possible to change the character of the material.

6. The experience gained in increasing the stability of earth roads over the same location will generally be useful in maintaining the stability of the subgrade. There is therefore much to be said in favour of gradually building up a highway system from the simple earth road, as this type when improved and stabilised will provide an excellent subgrade when traffic demands are such that a more permanent type of road surface is required. The most common methods of improving a bad subgrade are:—

1. Placing a layer of granular materials immediately under the concrete slab.
2. Mixing other materials with the subgrade soil.
3. Increasing the depth of the side ditches.
4. Placing drains along the sides of the concrete slab and parallel to it.
5. Proper drainage of all porous strata which may become a water bearing.

7. A layer of granular material immediately under the slab is usually quite economical and easy to apply. This porous layer must however be provided with proper drainage otherwise it will simply collect moisture and the bad condition will merely be aggravated. The materials that are usually mixed with unstable subgrades are sand, gravel, crushed stone, slag, or cinders—the aim being to alter the characteristics of the subgrade material so that it will have a low volume change and improved supporting power.

8. These materials may be used as a separate layer between the concrete and the soil or harrowed into the subgrade to form a separate crust. Increasing the depth of the side ditches will facilitate the drainage of the surface run off especially during the wet weather. Drains along the edge of the road slab will prevent surface water from entering the subgrade. The problem of a bad subgrade may possibly be met by strengthening the concrete slab, but is usually more economical to improve the subgrade materials.

9. The one thing to keep continually in mind is that the subgrade should support the slab UNIFORMLY. No matter how yielding the soil, if it supports the slab evenly it will not cause cracking. If a very hard soil is left in ridges of compacted earth separated by softer material, cracks are inevitable. Concrete roads traversing swamps, for example, have surprised everyone by the absence of cracking, while similar pavements built over old, compacted, macadam or gravel have been disfigured by a network of cracks. The explanation is simple. The soft, swampy soil supports the slab much as water supports a boat and there is no excessive bending; the hard ridges of macadam, interspersed by softer material, used to fill in depressions support the slab like the knife edges of a testing machine. Heavy loads cause excessive bending and the slab ultimately cracks over the ridge. Usually the crown of an old macadam or gravel road is greater than is required for concrete, it is therefore scraped off and used to widen the subgrade, leaving a solid ridge of old metal on the quarter points, a loosened center section and edges made of the newly rolled material which was scraped from the center joint.

10. The remedy is to loosen the old material until the full width of the subgrade, is UNIFORMLY SOFT, then roll it until it is uniformly hard. The principal value of the roller is to smooth out lumps, discover soft places, and consolidate embankments as they are being built up. A light roller will do this as well as a heavy one; most engineers prefer one weighing 5 tons or less. A heavy roller compresses some types of soil too much, so that they swell while the concrete is hardening, causing cracking.

A consideration of the concrete in the slab.

11. Before a concrete road slab can be economically designed it is necessary to have as full a knowledge as possible of the properties and characteristics of this structural material. In the case of steel we have had this full knowledge for many years, but it is only recently that concrete design has been brought into line with steel.

12. Let us follow the behaviour of a Portland Cement Concrete road slab from the time it is placed on the subgrade until after the road is opened and operated under traffic. Almost as soon as the concrete is placed it begins to harden or set. It has little strength yet, even at this stage it is subject to certain stresses. The surface begins to dry and this is assisted by wind or hot dry weather. This loss of moisture produces shrinkage and the concrete has so far insufficient strength to resist this. Hair cracks will quickly appear, and to counteract this the surface of the concrete must be kept moist from the earliest possible moment and kept in this condition until such time as the material has attained sufficient strength to resist these stresses. The subgrade may also be the cause of a certain amount of loss of moisture from the underside of the slab. This also has the effect of causing shrinkage in the concrete and incidentally may cause a considerable change in the volume of the soil with a resultant strain in the slab. To counteract this tarred paper over the subgrade has been used with considerable success and is now common practice in England.

13. It is important therefore to have the subgrade thoroughly moist when the concrete is laid so that there will be no tendency to draw the moisture from the concrete. When shrinkage of the concrete occurs

the slab as a whole tends to move on the subgrade. This movement is resisted by friction between the slab and the subgrade and if this is allowed to develop it will soon exceed the tensile strength of the green concrete. Again we see the importance of keeping the concrete moist during the early period of its existence. If the concrete slab has been divided by expansion joints at sufficiently frequent intervals this contraction is taken care of. If not, the small tensile strength of the concrete will be exceeded and transverse cracks will be formed to relieve this tension. The greater the tensile strength which the concrete has attained at this stage the less the liability of the concrete to crack.

14. Another phenomenon which takes place in a concrete slab is that of warping. This is due to the difference in temperature between the upper and lower surfaces. During the heat of the day the centre domes up and at night the sides curl up. This induces bending stresses in the slab due to its own weight. Any curing methods therefore, that will reduce the difference in temperature between the top and bottom of the slab will assist in overcoming the possible weakening of the slab due to warping.

15. The same factors which cause contraction of the concrete also cause expansion, but generally the early compressive strength is sufficiently high to resist it. Immediately traffic is allowed on the road, heavy wheel loads are introduced. If the concrete has been well laid and finished, these loads will move smoothly, but if the necessary care has not been taken severe impact will accompany the movement.

The design of concrete road slab.

16. *Width.*—It is customary to allow a 10-foot width for each lane of anticipated traffic. The slab therefore should be in multiples of ten.

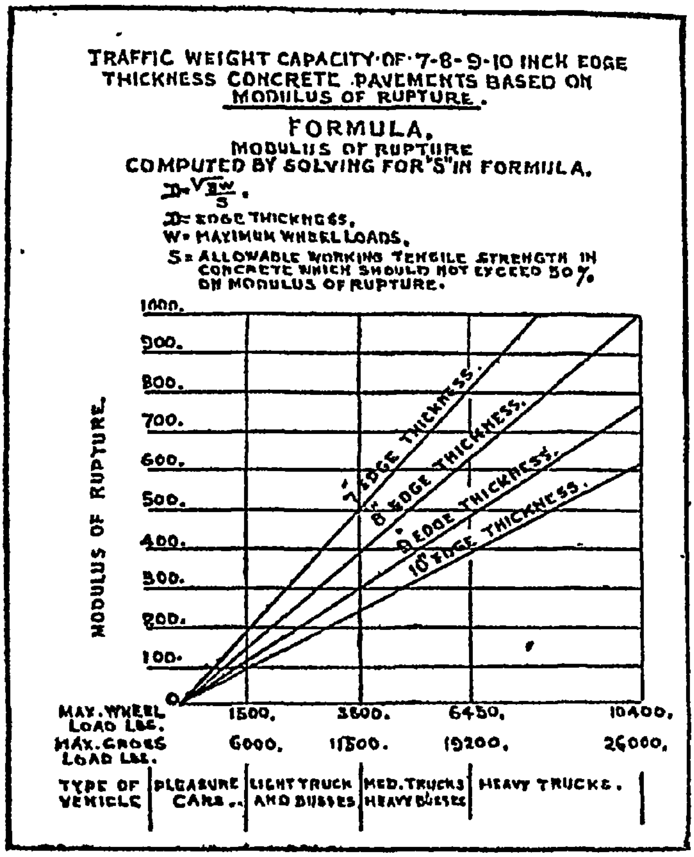
17. *Thickness.*—Tests and actual experience have shown that the edge of a pavement should be thicker or stronger than the central portion. This can be best illustrated by imagining a truck wheel; in the centre it is supported by a full circle of concrete, on the edge by a half circle and at a corner by only a quarter of a circle. It seems obvious that if a half or quarter of a circle of concrete is to support a load it must be thicker or stronger than the full circle which carries the same load. Both mathematical analysis and tests show that the maximum fibre stress is developed when the load is on the edge of the slab, instead of at a corner but a corner formula, checks so well with actual results that it has come into general use. This formula advocated by the Permanent International Association of Road Congresses and is:—

$$D \text{ (the edge thickness)} = \sqrt{\frac{3W}{S}}$$

Where W=the wheel load in pounds, S=the maximum allowable fibre stress in pounds per sq. inch., usually taken as ½ the modulus of rupture, or=the allowable tensile stress of the concrete at the top of the slab=200 to 300 lbs./sq. in.

18. Tests indicate that uniform strength is obtained in the slab when the thickness of the central portion is approximately seven-tenths of the edge thickness, provided that a longitudinal centre joint of a type-

capable of transferring the load is used, otherwise there would have to be a provision for increasing the strength of the interior edge of the half slab. For example, a concrete mixture designed for a compressive strength at 28 days of 3,000 lbs. per sq. inch would have a modulus of rupture of 250 lbs. per sq. inch.



19. *Fatigue.*—Tests carried out to determine how great a load concrete would carry before repeated applications would cause failures indicate that loads over 55 per cent. of the single load which would cause failure would break concrete if they were repeated several thousand times. This possibility of fatigue therefore makes it necessary to reduce the allowable fibre stress to one half that which will cause failure if applied only once. Provision for usual impact requires about the same reduction in the working fibre stress. Since however impact and fatigue do not often operate concurrently and the road slab increases in strength with age before the many applications of loads required to produce fatigue could be applied, a factor of safety of two is considered sufficient to cover both possibilities, and the fibre stress is taken as half the expected ultimate modulus of rupture.

20. *Transverse Strength.*—The transverse strength of granular brittle materials like mortars and concretes is best expressed by the modulus of Rupture. The modulus of rupture is the apparent stress in the extreme fibre of a transverse test specimen under the load which produces rupture.

For specimens of rectangular section of breadth b and height h, loaded centrally on a span l, the breaking load being W, the modulus of rupture is computed by the formula—

$$\text{Modulus of rupture} = \frac{3Wl}{2bh^2}$$

21. The extreme fibre stress thus computed is not the actual fibre stress because the formula involves the inaccurate assumption that the material deforms elastically for all stresses up to rupture. The comparative relations between results are not affected by this inaccuracy of the formula, however, when the tests compared are made upon specimens of similar material, because the computed values of the modulus of rupture are very nearly proportional to the actual stresses. Since the extreme fibre stresses on the tension side and on the compression side of a beam of homogenous material are equal, and the tensile strength of mortar or concrete is only a small fraction of the compressive strength, the transverse strength of mortar or concrete is almost wholly dependent upon the tensile strength. The modulus of rupture found in transverse tests will invariably be considerably in excess of the tensile strength, however, because the computed stress in the extreme fibre considerably exceeds the actual stress.

21A. *Joints.*—Concrete like most other materials expands and contracts with changes in moisture content and temperature. The generally accepted co-efficient for change in dimension because of change in temperature is 0·0000055 foot per foot of length, per degree F. The highest temperature expected in a concrete pavement is approximately 135°F., the lowest at which it can be laid is 35°F., making a possible maximum temperature difference of 100°F. The change in length from the absolutely dry to the saturated condition is about 0·0005 foot per foot of length. If a dry slab 100 feet long at a temperature of 35°F., were saturated and raised to 135°F., it would become about one inch longer. As pavement are saturated when built and are usually laid when the temperature is above 50°F., expansion should not exceed one inch per hundred feet.

22. Unless some provision is made for this expansion the forces developed may be great enough to raise or even shatter the concrete. That is prevented by installing joints which divide the pavement into separate slabs with a space between for expansion. As concrete cools or dries it contracts an amount approximately equal to that given for expansion. A contracting slab must slide itself over the subgrade. The forces of contraction, opposed by the friction between the bottom of the slab and the subgrade, set up tensile stresses in the concrete. When these tensile stresses exceed the strength of the concrete, transverse cracks will form. Such cracking is prevented by the installation of transverse joints of either the expansion or contraction type.

23. The ideal interval between transverse joints is the maximum at which no intermediate cracks will form. This depends upon the strength of the concrete, the weight of the slab, the sliding friction between slab and subgrade and, to some extent upon the amount of reinforcement if any. As there is a possible expansion of about one inch per hundred lineal feet of slab, provision for this amount should be allowed. Expansion joints are filled with some compressible material plastic enough to be pushed from the joint under pressure but sufficiently stiff to resist melting on the hottest days. Experience indicates that a joint interval of 30 to 35 feet is sound practice for Indian conditions.

24. Transverse joints should never be staggered unless adjacent slabs are completely separated by longitudinal joints containing expansion material so that independent longitudinal movement is assured. Longitudinal joints are put in to prevent longitudinal cracking. This cracking may be caused by the warping of the slab or by subgrade heaving or settlement. Experience indicates that all 2-lane pavements should be so divided. For wider streets longitudinal joints should divide the pavement into slabs not more than 15 feet wide. If only one joint is needed it is located on the centre line. If more joints are needed they should be located where they will receive the least wear from wheels which run along them.

25. *Longitudinal Construction Joints.*—There are several varieties of these and opinions differ as to the efficiency of each. The tongue and groove construction is very common in America but it is only suitable where the thickness of the slab is 8″ or more. Steel dowels are frequently used to transfer the load across the joint. The length of these dowels is usually 4 feet and ½″ diameter and placed in the centre of the slabs at 5 feet centres. Another method is to thicken the edges of the slabs at the centre longitudinal joint making each strip a separate unit.

26. *Transverse Expansion Joints.*—Dowel bars are put across transverse expansion joints to prevent unequal heaving and to transmit loads from one slab to its neighbour. Dowels should be bonded in one slab but have the bond broken in the other by being coated with paint paper or heavy grease There should also be space left at the greased end into which the bar can slide. Both these precautions must be carefully observed to prevent severe damage at every joint. If the bond is not broken or no space is left at the end of the bar, then the bar will bend under the thrust of the expanding concrete, lift one slab and probably shatter the concrete. The space at the end may be formed by placing on the end of the bar a ball of compressible material, a metal cylinder, or anything else into which the bar can push. It should be about twice as deep as the width of the expansion joint.

27. The material used to break the bond between the dowels and concrete should not be too heavy, for if the bar fits into the concrete too loosely, one slab may be carrying maximum stress before the bar transmits much load to the other slab. A coating of form oil or heavy grease is sufficient. Dowels are supposed to transmit part of the load across the joint, but, since the amount of its bearing on the concrete cannot be determined, it is impossible to figure what diameter bars should have, to keep from crushing the concrete. Dowels must be smooth and are ordinarily ¾ inch round bars placed in the centre of each slab. It has been customary to install dowels at 2-foot intervals.

28. *Reinforcement.*—Opinions differ concerning the necessity for reinforcement. There is prevalent an erroneous idea that reinforcement is put in concrete pavement to increase its load-carrying capacity. That is not the case. To increase the beam strength of a pavement, steel would have to be placed in two layers, one near the top and the other near the bottom, since critical tensile stresses may occur either in the bottom or top of the slab. And it would have to be used in much larger amounts than has ever been considered feasible if it were to add appreciably to the pavement's strength. Additional load-carrying capacity can be secured more cheaply with additional thickness of concrete than with steel. Steel does, however, hold together any cracks that form, whether

those cracks are due to temperature or to loads, and should therefore prevent settlement and subsequent disintegration under increased impact. This is steel's only function in a concrete-pavement.

Camber.

29. Pavements are sloped from centre to sides so that water will drain from them. The less the slope the safer and more comfortable the pavement. Because concrete can be given a permanently even surface very little slope, or camber, is required to make concrete pavements drain. A camber of $\frac{1}{8}$ inch per foot of width from centre to gutter is sufficient for country roads but 3/16 inch is better for streets. No concrete pavement should be cambered more than $\frac{1}{4}$ inch per foot except where the slab is warped to fit between gutters of unequal elevation or to vary curb exposures. In those places half an inch per foot is permissible, but should not be used where it will cause cars, rounding a corner, to slide against the lower curb.

30. The section of a pavement may either be two planes or a curve. For the flat slopes used on concrete pavements the circular curve formula and parabolic formula give *identical* results, and the parabolic curve is much easier to design. The simplest way to apply the parabolic equation to pavement crowns is to divide the distance from the apex of the crown to the curb (or gutter, if the gutter is already in place) into equal spaces. Then if the total fall to the gutter is "y" inches, the fall to a point one-fourth the distance to the gutter is $(\frac{1}{4})^2$ y inches, to a point one-half the distance to the gutter is $(\frac{1}{2})^2$ y inches and three-fourths the distance to the gutter is $(\frac{3}{4})^2$ y inches.

The construction of concrete roads.

31. *Materials Suitable for Concrete Roads.*—The same qualities which characterize good aggregate that is, sand and stone for other types of concrete construction are desirable in aggregate for roads. These are: *Cleanness, hardness, toughness, low absorption, non-glassy surfaces* and *cubical shape*. Some of these qualities are even more important for concrete roads than for any other types of concrete. *Cleanness*, for example, is important because any dirt in the aggregate is likely to come to the surface of the slab and form a weak, porous, soft layer called "laitance" which scales off easily, leaving an unsightly rough-riding pavement. It is usually necessary to wash any sand, or gravel before they are used and crushed stone should be free from dust and dirt.

32. *Mixing Concrete.*—Time is the most important factor in mixing. Concrete of the quality common in roads is from 20 to 35 per cent. stronger when mixed two minutes than when mixed only 15 seconds. This is largely due to the increased workability secured with longer mixing and the possible decrease in the quantity of mixing water. Thorough mixing increases the uniformity of concrete. In tests to determine the effect of mixing time, specimens mixed for only 15 seconds showed an average variation from the average strength of 30 per cent., while those made of concrete mixed two minutes varied less than 10 per cent. Another advantage of thorough mixing is that it is of great assistance in securing watertight concrete. The speed of rotation of the mixer has little to do with thorough mixing within the commonly accepted limits of from 12 to 20 revolutions per minute. One minute should be absolute minimum mixing time.

33. *Placing Concrete.*—There are a few general precautions to be observed when placing concrete. Workmen should not track dust or mud into it nor should the subgrade be sprinkled in such a way that dust is thrown into the exposed edge of the slab. Workmen should not be allowed to roam around in the concrete after it has been struck off. Footmarks are usually filled with mortar largely composed of laitance and often show as depressions after a few years' wear. Whenever the mixer is shut down long enough for the concrete to commence hardening, a square butt joint should be made. Otherwise a sloping line of weakness will be left which may push up under the thrust of expansion or crack as the slab contracts. Even when the mixer is stopped for only 10 or 15 minutes the new and old concrete should be thoroughly sliced together with shovels to make sure that no cleavage plane is left. It is advisable to use concrete a little deficient in coarse material next to joints at noon and night stops. This is especially true of the first batch mixed in the morning, for some of its mortar paints the mixer drum and porous concrete is especially objectionable at joints.

34. *Joints.*—There is one thing of paramount importance in joint construction, that is to have the joint truly perpendicular to the surface of the pavement. If it is not perpendicular the pressure of expansion will cause one slab to slide on the sloping end of the other. Joints should run straight across the pavement if they are to look well and it is important that the filler be continuous from one edge of the slab to the other, for if even a small wedge of concrete spans the joint, spalling or cracking will probably follow. Expansion joints are usually made by installing premoulded filler just before the concrete is placed. The filler is held upright by a bulkhead staked in position. Metal bulkheads are better than plank because they are thin and easily removed without pushing the filler out of line.

35. "Poured joints" are sometimes preferred. When they are used a slightly wedge-shaped bulkhead is left in the slab when the pavement is finished. After the concrete has hardened enough so that it will not flow, the bulkhead is removed. The joint is completed by first cleaning the crevice with a pointed hook and then filling with hot bitumen. The chief advantage is that the stiff bulkhead is more easily held in the proper position. The joint may be inspected before it is filled and if it is not perpendicular to the surface the installation methods can be changed so that future joints will be right—an inspection which is nearly impossible with the premoulded type. There is some danger, however, of cracking the concrete a foot or two from the joint when the bulkhead is lifted, and if the bulkhead is pulled too late and the edges of slab are disturbed after hardening has progressed too far, the disturbed sections may later break loose from the slab.

36. To insure continuous expansion space from edge to edge, the filler should either be in one piece of the proper length or shorter pieces should be fastened securely end to end with clips. A ¼ inch expansion joint should be left around all manhole covers, poles, or other structures which protrude through the pavement. Some movement of the slab is certain to take place, and, unless allowance is made for these rigid structures, the pavement will be cracked. A piece of premoulded joint filler, held in place with a strand of wire, is the best. The dummy joint is a weakened plane made by cutting through the top 2 or 3 inches of the slab. The cutting tools may be the web of a "T" bar 10 or 12 feet

long, fastened to a plank for stiffness and provided with plow handles, or it may be a sharp-edged wheel which is run along a straight edge.

37. *Finishing.*—So far as public approval goes, a smooth-riding finish is the most important feature of a pavement. The average motorist knows nothing of the hours spent in testing materials, in design, or in securing the proper quality or quantity of slab; all he is interested is; "How smooth is it?" Finish also effects the life of a pavement, since a rough surface materially increases impact. A concrete pavement should not vary more than $\frac{1}{4}$ inch from a 10-foot straightedge laid parallel to the centre line.

38. The finishing machine as used in America is usually followed by a float from 12 to 16 or even 20 feet long, operated with its long axis parallel to the centre line of the pavement. It is made of plank about 3 inches thick and 10 inches wide, stiffened by a plank set on edge, along the top and provided with handles at each end. This longitudinal float, as it is called, is handled by two men, one at each end, who stand on bridges spanning the pavement. It is laid on the pavement at one edge and pulled towards the other edge with a wiping motion, levelling transverse ridges and other high spots and filling depressions.

39. The longitudinal float is an efficient tool for getting a smooth-riding surface because it operates at right angles to the screeds or belts. If the latter tools leave ridges, they are at right angles to the wheels or vehicles and so give those vehicles the maximum of bump. The longitudinal float eliminates those ridges, and any ridges it leaves are parallel to the wheel tracks and do not produce bumps. Following the longitudinal floating excess mortar and laitance are scraped from the surface with a straightedge mounted on a long handle. That is done to remove the thin layer of mortar that sometimes covers the more dense concrete, because it is that layer which is likely to scale off. Scraping also removes the small corrugations not detected by the straightedge and produces a smoother-riding pavement. In India this is usually done by drawing a gunny bag transversely across the slab.

40. The next operation is testing the surface by means of a straight. A straightedge about 10 feet long mounted on a long handle is held so that it barely touches the concrete. This is done at intervals of 3 or 4 feet transversely with the straightedge parallel to the centre line. Successive straightedging should overlap by $\frac{1}{2}$ the length of the straightedge. Any high spots discovered are removed and low spots filled. Disturbed places are smoothed with a long-handled float and the surface is again straightedged to see that it is now uniformly even.

41. The final finishing operation is belting, which should be done after the water sheen has disappeared from the concrete. A belt of rubber, fabric, or a thin board, about 10 inches wide and 2 feet longer than the width of the pavement, is laid on the pavement transversely and dragged forward with a sawing motion. The object of belting is the even distribution of the surface mortar and the production of granular, gritty surface that tyres can grip firmly. A final finish is sometimes given by dragging a strip of canvas, about 3 feet wide, over the surface. That gives a very even, gritty surface and is highly recommended. Sometimes the surface is broken up into tiny ridges by brooming. An ordinary street broom, with medium coarse fibres, is attached to a long handle. After the other finishing operations are completed this broom is dragged lightly from centre to sides of the slab.

42. *Hand Finishing.*—Hand finishing is like machine finishing except that the striking off and consolidating are done with hand screeds. These are of wood or metal, shaped to the crown of the pavement, shod with steel on the lower face and having plow handles on each end. They are usually specified to weigh at least 15 pounds per lineal foot and must be constructed so that they will not sag.

Summary of finishing operations.

43. *Machine Finishing*—

1. Screed and compress.
2. Longitudinal float or belting.
3. Scrape.
4. Straightedge
   Correct surface
   Float disturbed places.
5. Belt.

Hand Finishing—

1. Screed.
2. Tamp.
3. Longitudinal float or hand float or belting.
4. Scrape.
5. Straightedge
   Correct surface
   Float disturbed places.
6. Belt.

Too much tamping or any over-finishing which brings much mortar to the surface, seems to be responsible for most of the surface scaling, and should be guarded against.

44. The above finishing operations are those in vogue in other countries. In India however the number of operations is reduced and consists usually of:—

1. Tamping which includes a certain amount of screeding.
2. Floating with a short wooden hand float.
3. Drawing a gunny bag lightly across the surface to remove the superfluous moisture.

45. High joints are a frequent source of annoyance. Every exposed joint should be finished with a float, split in the middle to form a space for the joint filler so that the concrete on both sides of the joint can be finished simultaneously. Then it should be carefully checked with a straightedge notched in the centre to form a space for protruding joint filler. All edges of the slab, including both longitudinal and transverse joints, should be rounded with an edger having a radius of $\frac{3}{8}$ inch.

46. Sometimes the slab is also straightedged the morning after it is laid and any high spots discovered are reduced by rubbing with a carborundum stone. Rubbed spots do not look well but rubbing does not damage the slab. Its chief value is as a penalty to make contractors careful to get the surface right before the concrete hardens.

47. *Curing.*—Curing is the treatment or protection given concrete during the hardening period. Pavements are either air-cured, water-cured cured with calcium chloride or a surface coating of some waterproof material which prevents evaporation. When concrete is mixed it contains sufficient water to hydrate the cement. As soon as it leaves the mixer it begins to lose moisture by evaporation and absorption. In hot, dry, windy weather the comparatively thin slabs used in paving dry out very rapidly. This drying has two effects: (1), There is left insufficient moisture to complete the hydration of the cement and (2), the concrete shrinks as it dries and tensile stresses are set up while the concrete is too weak to withstand them. The result is a concrete whose strength is only 70 or 80 per cent. of what it would be if it had been kept wet, and a slab which is excessively hair cracked. When to this drying is added the action of a summer sun, there is produced a chalky, weak, porous surface layer whose resistance to wear is low.

48. Whatever method of curing is provided, except bituminous coating, a layer of canvas or gunny bags should be put on the slab as soon as it can be done without marring the concrete. This should be kept wet by frequent sprinkling for several hours, until it can be replaced by the approved curing agent. It is especially important to keep the pavement wet the first few days and the first few hours are most important of all. Strength lost by lack of moisture during the first few hours and days cannot be regained by subsequent curing.

49. Water curing is the surest and safest. The pavement is kept wet during the early hardening period either by a blanket of earth, hay, straw, by ponds of water held on the surface by small earth bunds, or by continuous sprinkling. Two inches of earth or 6 inches of hay or straw are usually specified. These must be sprinkled frequently so that they keep the slab damp at all times. Hay and straw hold moisture longer than earth. Sand is also satisfactory. Sprinkling is often more convenient than a wet covering for city streets. Intermittent sprinkling by hand is not advisable because the pavement is then dry most of the time and is cooled too suddenly when sprinkling starts, but a system of automatic sprinklers which keep the concrete wet continuously is satisfactory. A hot pavement should not be cooled suddenly by the application of a considerable quantity of cold water, for the resulting rapid contraction may cause cracking.

50. Several patented processes have recently been introduced utilizing a thin coating of linseed oil or fluxed or emulsified asphalt to prevent evaporation from the surface of a concrete pavement. These are applied with a paint spray immediately after the final finishing operation. Complete tests are advisable before they can be given unqualified approval.

Mr. W. J. Turnbull (the Author): Mr. Chairman and gentlemen, in introducing my paper on concrete roads I have a few additional remarks to make which possibly may lead to a certain amount of constructive discussion.

It has been for many years the customary practice to thicken the longitudinal edges of concrete slabs in order to obtain a balanced design, but in this connection I wish to quote an expression of opinion of an English authority who states as follows:—

> "Many of the earlier ideas on the design of concrete roads have proved in practice to be fallacious. For instance, as a result of extensive tests it was recommended that the edges of road slabs should be 2 inches or 3 inches thicker than the remainder, with consequent complications in the excavation and shaping of the formation."
>
> "It was claimed that the thickened edges would prevent corner breaks in strip construction, but the simpler procedure of using additional reinforcement in the top of the slab at corners and a tongue-and-grove longitudinal joint has proved to be more effective and less costly. When roads are laid with longitudinal and transverse joints, it is found that corner breaks are minimised by inserting top reinforcement for a width of 3 feet from the edges of the panels and overlapping this reinforcement at the corners so that the weight of steel is doubled in an area measuring 3 ft. by 3 ft. at each corner. A further precaution against corner cracks is to ensure that the concrete is thoroughly rammed at the corners of the slabs, where normally this operation might not be so carefully carried out."

The above opinion is, I think, purely a question of economy. In India, it is usually cheaper to thicken the edges than to insert reinforcement, but in cases where it is desired not to disturb the existing base, reinforcement at the sides would be the obvious design. That is a question which might be discussed, I think.

Another point is this. Many engineers not conversant with concrete roads raise the objection that in the event of any irregular wear taking place such as shallow ruts, etc., it would be exceedingly difficult to make the necessary repairs to bring the surface to its original level. It is quite possible that such wear might occur where heavy steel tyred traffic is compelled to track on narrow strips of concrete such as haunches, etc. To enable these shallow ruts to be repaired easily, the following procedure has been adopted in England:—

The concrete is deposited to about $1\frac{1}{2}''$ below the finished level and then cotton fabric or loosely woven jute is laid on this surface. The balance of the slab is then laid and finished in the usual manner. It is claimed that the insertion of the cotton fabric does not weaken the strength of the road and facilitates the removal of this thin surface course for any repairs. It would appear to form a cleavage plane.

The third point is on the subject of the use of longitudinal shear bars. Corners formed by transverse joints or cracks are frequently protected in America by the following expedient. A longitudinal bar $\frac{3}{4}''$ dia. is inserted about $6''$ from the edge of the slab and parallel to it. It is painted and greased and extends from end to end of the slab. It is claimed that these edge or shear bars reduce corner stresses 20 per cent.

The purpose of painting and greasing these bars is to break the bond with the concrete so as to permit free longitudinal movement of the bar in the concrete and to present intact the full section of the bar for shear bearing and bending in load transmission. (Applause.)

Chairman: Will Mr. Surati kindly introduce Paper No. 9?

Mr. H. M. Surati, Divisional Engineer, Roads, Hyderabad, then submitted Mr. Zeman's Paper, No. 9, for discussion.

(*Paper No. 9.*)

Concrete Roads in Hyderabad (Deccan).

By

M. A. Zeman, Chief Engineer, Drainage Department, (Hyderabad, Deccan).

1. Hyderabad. the Capital of the State, has an area of 27·44 square miles and a population of 4,66,894 (including the Cantonments). It has all the amenities of modern cities such as Electric and Telephone services, Drainage and Water Supply. The total length of roads is approximately 130 miles most of which are constructed of metal or gravel.

2. *Adoption of cement concrete roads.*—With the advent and rapid increase of motor traffic during the last decade, the old metal and gravel roads could not be economically maintained in an efficient state of repair and the dust nuisance was becoming unbearable. The authorities. realising the danger to public health and the necessity of good and dustless surface, deputed their Engineers to investigate, who after visiting important cities in India, adopted Cement Concrete as one of the best and most economical road surface suitable to the local conditions available in the State.

3. *General Details.*—Between the years 1929 and 1932 the State has constructed over 21 miles of cement concrete roads in the City. The roads have been constructed in bays of 30 feet lengths with transverse joints at 60 degrees to the axis of the road. The road widths are generally 40 feet. The central 19 feet belt is constructed of rich cement concrete having a thickness of 6 inches in the centre and 9 inches at the sides with a camber of 1 in 60. The side berms which are constructed at present of either lime concrete or macadam sealed with Bituminous Emulsion or of gravel, will be cement concreted later on if required.

4. *Sub Grade.*—In constructing the cement roads as little disturbance as possible was caused to the existing surfaces but where it was considered necessary levels were adjusted in order to avoid sharp changes of grades.

5. *Method of Construction.*—Cement concrete was laid in alternate bays giving an interval of 3 to 5 days. After preparing and rolling the sub grade to the required gradient, channel irons 30 ft. in length were used for the side forms and were fixed in position by means of 1 inch square steel pins driven well into the sub grade. The transverse forms were of timber 3 inches thick protected at top by a 3/8 inch flat iron and the face towards the concrete by 1/16 inch plate. Provision for the free movement of the concrete slab was effected by laying over the sub grade 3/4 inch thickness of clean sand.

Cement concrete was laid in two layers, the bottom being tamped by small hand tampers and left rough to be immediately covered by the top layer. Final consolidation was effected by means of heavy iron tampers working across the side forms and weighing about 25 lbs. per foot length, and with a 6 inches wide bottom plate. The surface was finished by means of long wooden floats all edges of the slab being curved to 1/2 inches radius.

6. *Proportions.*—Different proportions were tried for the bottom and top courses. The proportions of cement, sand and metal finally adopted from the point of economy and efficiency were 1 to $2\frac{1}{2}$ to 5 for the bottom and 1 to $1\frac{3}{4}$ to $3\frac{1}{2}$

for the top course. Char Minar brand cement which is manufactured in the State has been used throughout. Well graded clean river sand passing a sieve of 64 meshes to one square inch and hand broken granite metal graded from $2\frac{1}{2}$ inches size to $1\frac{1}{2}$ inches for the bottom layer were used and for the top layer an addition of 1 inch to $1\frac{1}{2}$ inches size of granite was made in the proportion of 1 to 2.

7. *Joints.*—No expansion joints were made but only constructional joints painted with bitumen were left. The rounded edges of the joints were further protected by a thin layer of bitumen sprinkled with sand before opening the road to traffic.

8. *Reinforcement.*—No reinforcement was used except over recently filled trenches and around drainage and water supply manholes or similar substructures. No reinforcement was deemed to be necessary as the sub grade consisting of the old gravel roads which had seen years of traffic, was found to provide good foundation. Moreover, the traffic consisting mostly of motors and motor buses, horse drawn vehicles with iron or rubber tyres and 1 to $1\frac{1}{2}$ tons two wheel bullock carts with iron tyres is light and not heavy.

9. *Lime Concrete Berms.*—With a view to further economise, the side berms as mentioned above, are constructed of 6 inches thick lime cement concrete in the proportion of 1 part of lime, 1 part of cement, 5 parts of sand and 8 parts of stone and finished in the same way as the central belt. The concrete was covered with old cement bags kept wet for 3 days and a liquid preparation of alum (48 ounces to 1 gallon) was sprayed daily on the surface. On the fourth day the whole surface was covered with 2 inches to 3 inches of sand and kept thoroughly wet at least for 7 days in case of cement concrete and 21 days for lime concrete. The ultimate crushing strength of this lime concrete in a 6 inches cube is 25, 30, 32 and 33 tons, at the ages of 7, 14, 21 and 28 days respectively. The lime is machine ground and is slightly hydraulic. The cost of lime concrete is Rs. 2-12-0 per sq. yard as against Rs. 4-4-0 per sq. yard of the central belt and its strength and life is found to be much more than that of either cement macadam or bitumen painted macadam.

10. *Subsequent Improvement.*—In the more recent construction of cement concrete roads certain alterations in the design and execution have been made following the experience gained in the earlier construction. The 60 degree transverse joints have been given up and right angle joints which facilitate better tamping and provide greater strength at the corners of the slabs have been adopted. So far no difference has been observed in the riding qualities of the road which the 60 degree joint was supposed to improve and eliminate shocks over the joints due to any difference of levels caused by either unequal settlement or expansion. In fact the right angle joint seems to give more comfortable travel over joints. Secondly, the difficulties experienced in laying a full central belt of 19 feet width at one operation and the tendency to cause variable cambers through the sagging of a long heavy tamper have resulted in the adoption of 10 feet wide strips with a central constructional joint, which also serves the purpose of a guide to the traffic.

11. *Slipperiness.*—So far there has been no slipperiness observed on these roads which may be attributed firstly to the grading of the aggregate and the difficulty with which the granite will take up even smoothness under the traffic. Secondly, the sand consisting chiefly of disintegrated rock is coarse

grained and does not take up any polish but wears under traffic. With all the difference in strength between the individual constituent of the cement concrete, the surface has been wearing evenly without any roughness whatsoever. Lastly, the proportion of 1 to 2 to $3\frac{1}{2}$ and 1 to $1\frac{3}{4}$ to $3\frac{1}{2}$ in the case of the wearing coat is not so rich as to give that polish to the surface which is found in the richer proportions. Another cause which keeps the surface non-slippery may be attributed to the horse and bullock drawn traffic with their wobbling iron tyred wheels grinding the surface instead of polishing it.

12. *Maintenance and Economy.*—The cost of maintenance of the cement concrete road has been negligible as compared to other types of roads in the City. The annual cost per square yard for cement concrete is one sixth of an anna, or two pies, as compared with three annas for the other equally costly bituminous roads in the City. The savings on a road one mile long and forty feet wide, are computed to be Rs. 60,133 and Rs. 1,61,333 at the end of 12 and 24 years allowing 6 per cent. compound interest on all costs, as compared with 4 inches thick bituminous grouted and sealed road surfaces with 9 inches soling and 6 inches macadam. Besides being economical, the use of cement which is manufactured in the State and is of excellent quality is advocated, whereas nearly 50 to 60 per cent. of the amount expanded on Asphalt roads goes out of the State for the purchase of Asphalt.

13. *Results of experience on cement concrete roads* :—

1. The grades, where there is bullock and horse drawn traffic should not exceed 1 in 25 and that too for short distances : only from 200 to 300 feet. A ruling grade of 1 in 30 is preferable for city roads.
2. There should be no sharp changes of grades, which irrespective of being unsightly, affect the riding quality of the road.
3. Always provide a central joint with 10 feet strips and tamp transversely. If no central joints are provided, tamp longitudinally with transverse joints closer.
4. Use only long wooden floats 8 to 10 feet for finishing the surface working always longitudinally and parallel to the axis of the road with light pressure overlapping the previous floated surface by 1 to 2 feet.

Subsequent Notes.

14. It is now nearly five years since the laying of cement concrete roads was begun on an extensive scale in the City of Hyderabad and about 22 miles of main roads have been already cement concreted up to the end of 1341 F. (September 1932 A. D.). There are another 7 miles of roads on the roads probably which are to be cement concreted during the current and the following two years which will make a total of about 29 miles of cement concrete roads, probably the highest mileage of this type of road in the whole of India. During these five years all the roads without any exception have been giving excellent service throughout all the seasons. There has not been a single pot-hole, nor uneven wearing nor unequal settlement nor anything as a matter of fact to complain of. The thin coat or scum of cement mortar took more than two years of wear off. And now that the mosaic has appeared, the wearing is observed to be much slower—thanks to the excellent quality of the Shahabad

cement and granite stones presenting a good grip and foothold to the traffic and a pleasing surface to ride on.

15. Once cement concrete roads are properly laid, paying particular attention to the right proportion and quality of metal, sand, cement and water, mixing, laying, tamping and curing, it requires very little attention beyond the maintenance of joints which are filled once or twice in a year, depending upon the amount and nature of traffic, without causing the least obstruction or inconvenience to the traffic or public in general. Maintenance costs vary from $1\frac{1}{2}$ to $2\frac{1}{4}$ pies per square yard which is negligible compared to other road surfaces. It is estimated that the cement concrete roads in Hyderabad will last from 12 to 15 years and it is too early to say what treatment they should receive after this period. But it is believed that a 3 inch thick cement concrete wearing coat can be easily put on or that the old road can serve as a foundation to an asphalt surface.

16. It will not be out of place to consider here a few of the advantages of the cement concrete road over the Asphalt Roads in the City of Hyderabad :—

(1) With minimum disturbance or cutting of the old existing well consolidated murum or metal surface, it is possible to lay the cement concrete road as against the deep cuttings of eighteen inches to 2 feet required for an Asphalt surface on 9 inches to 12 inches soling with 6 inches macadam and 4 inches thick Asphalt grouted carpet.

(2) The cement concrete road can be laid very rapidly with less inconvenience to the public at large and less materials and time are required as compared to an Asphalt road.

(3) The initial cost of a cement concrete road is a little more (about 3 to 4 annas per square yard) than that of an Asphalt road. But there is considerable saving in the maintenance cost of cement concrete road as compared to Asphalt which at the end of 12 and 24 years amounts to Rs. 60,133 and Rs. 1,61,333 respectively on a road, 40 feet wide and one mile long, charging 6 per cent. compound interest on the total outlay.

(4) A well laid cement concrete road is smooth, dustless, sanitary, easily cleaned. Its joints and light colour add to the visibility at night. It possesses low tractive resistance, but with excellent adhesion both during dry and wet seasons, tending to decrease transportation costs, wear and tear of vehicles and accidents due to skidding. On account of low heat absorption of cement concrete it is more comfortable for pedestrians than Asphalt during Summer, while on the other hand, the Asphalt road offers greater tractive resistance in Summer and less adhesion during wet seasons thereby causing skids.

(5) Last but not least, all materials including cement for a cement concrete road are available locally in the State, whereas Asphalt has to be imported.

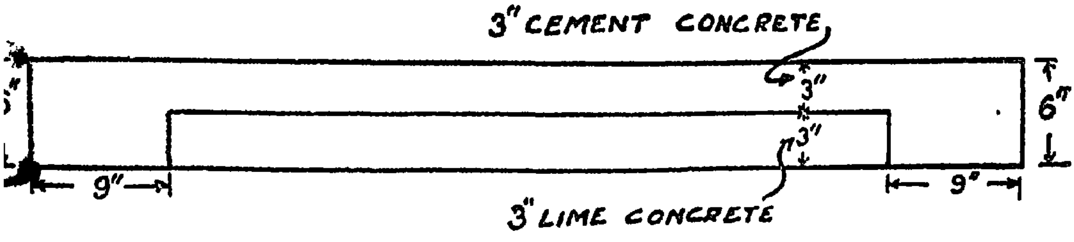
17. In conclusion, the cement concrete roads in Hyderabad have proved a great success and appear to be the best surface for all cities in general where there is heavy traffic and particularly for the bullock carts with iron-tyred wheels which are the principal vehicles for the transport of goods in India from generations past and will probably remain so for generations to come, for the simple reason that power used for agriculture in India is invariably derived from them.

Mr. H. M. Surati (on behalf of the author): Mr. Chairman and Gentlemen. as Mr. Zeman, the author of this paper is unable to attend this Congress and to introduce this paper himself· I am asked to convey his regrets and to introduce the Paper on his behalf, and I hope to be able to answer any question or criticism to the best of my abilities.

On the subject proper, I have nothing much to add except in general terms. As we all know, the science of road construction during the last decade or two has been and is demanding considerable attention of the engineers and the authorities concerned due to the changed conditions, and I am sure you will agree with me when I say that the problem is not solved from all its aspects whether of cost, construction or maintenance. The science has not yet reached that stage when one can straight away say without fear of contradiction that such and such specifications should be used for such and such conditions, as one would do in finding out the size of joists and beams in the design of a floor.

But suffice to say that the road to withstand the modern conditions of traffic, and especially that of a big city, should have practically unyielding foundations, the materials of which it is composed should not move under traffic when once it is laid or wear rapidly and unevenly, and of course, it should be dust proof. These essentials are more or less combined to a greater extent, so far as I know, in the cement concrete. But the first cost is rather excessive, hence difficult to finance.

To those who are interested in this material, I would recommend to experiment on the following lines to reduce the cost. We in Hyderabad have tried to reduce the thickness of cement concrete to 3 inches by providing 3 inches lime concrete as the lower bottom course or foundation. The lime concrete was immediately followed by cement concrete of 1: 2½ : 5 proportion, and both were well bonded to act as one solid mass. Around all edges and joints for a width of 9 cement concrete was wholly provided. To make the point more clear. I will just give you a rough sketch



This type of construction was adopted for the sides of an important thoroughfare 70 feet wide over which the slow-moving heavily loaded, iron-tyred traffic is generally moving. It is now more than two years since the road is under use, and so far the surface is standing up well. This is all I have to say. (Applause.)

DISCUSSIONS ON PAPERS Nos. 7, 8 AND 9.

Chairman: Gentlemen, the three Papers are now open for discussion. I should be glad if those wishing to speak would kindly come forward.

Mr. H. A. Hyde: On the subject of reinforcing of cement concrete roads, I would like to ask Mr. Turnbull—has the system of X-angle loop. forcement been tried extensively and is it of very great value?

Mr. N. V. Modak: Mr. Chairman and Gentlemen, I should like to say a few words on Mr. Turnbull's paper. In the first place I must congratulate the author in presenting to this Congress the principal features of cement concrete roads in a concise form in this paper. Cement concrete roads in India are of a recent growth and the literature available on this subject is very meagre. It is therefore gratifying to see the author giving the benefit of his experience in the construction of concrete roads all over India. It is really unfortunate that it has not been possible for him to treat this subject in greater detail as in that case the paper would have been a guide to those engaged in the construction of concrete roads all over India.

The importance of the preparation of subgrade cannot be over-estimated in the case of roads subject to heavy traffic. On it, depends the life of the carpet or pavement. The author has rightly stressed the importance of moisture content in the materials comprising the subgrade, and the consequent change in volume. A well consolidated waterbound macadam offers an excellent subgrade provided it is properly drained. It is, however, necessary as a precautionary measure to spread a layer of ½ inch of sand carpet as an insulating layer on which a concrete slab should be laid on a uniform subgrade so that varying stresses may not be developed in the concrete after it is laid.

It is absolutely essential to know the behaviour of concrete while it is being laid and after it has begun to act, especially on Indian soil where the range of maximum and minimum temperatures is great and the stresses developed in concrete due either to expansion or contraction while setting or to bending while warping very considerably.

Regarding the design of a concrete slab for a road, it would be instructive to know from the author whether the slab should be designed for the absolute maximum load it may be called upon to carry occasionally or for average traffic load likely to pass over it. It would appear on the face of it that it should be designed for the heaviest load likely to pass over it, but the section would be larger than necessary and the road pavement more costly. For a ten ton roller, for instance, the wheel load would be about 3·94 tons and with 50 per cent. impact the total wheel load would amount to 5·91 tons or 13,238 lbs. The thickness of the slab at the edge would, according to the formula adopted by the VIth International Road Congress and quoted by the author, work out to 11½″ and that at the centre to 8″.

Then the question about the allowance for impact is another controversial point in the design of a concrete road slab. It is contended that 50 per cent should be allowed for impact as a safe allowance as there are many unknown factors during construction which tend to reduce the strength of concrete.

It is also necessary to have as few joints as possible. In practice, however, it is not feasible to lay concrete in greater lengths than 40 to 60 feet, where continuous system of laying is adopted. In alternate bay system the usual lengths are 15 to 16 feet. Due to long range of temperature variation and consequent greater allowance for expansion and contraction the author recommends a joint interval of 30 to 35 feet. In practice, this is found to be the best working length.

Now, there are a number of ways by which the joints, either longitudinal or transverse are filled in, but the most efficient filler in the joint would be rubber. Its cost, of course, would be prohibitive. Premoulded bitumen is generally used, but during hot weather the bitumen is squeezed out leaving the joint more or less open and the edges of the concrete slab are knocked off by the passing wheels. This action is detrimental especially where the subgrade is yielding.

Then another question about the concrete roads is, that where the work has to be carried out under traffic conditions, it causes a lot of inconvenience to the traffic because curing takes from 14 to 21 days. In Bombay, it is found that curing causes great inconvenience, and it is a matter in which some improvement appears to be desirable. There are, of course as I say, limitations to every mode of construction. Concrete roads are not suitable for every or all kinds of traffic. We have now had sufficient experience of concrete roads in Bombay, and we find that for heavy traffic, especially from the docks, a concrete road is not suitable. The Argyle Road which has cost about Rs. 8 per square yard has given a lot of trouble at the joints, because the traffic we are getting is extra heavy, consisting of heavy steel tyred vehicles and bullock-carts. The Cement Marketing Company of India has criticised me for not adopting concrete for Bombay roads, but it has not been done, not because of the question of strength, but because of the question of economy.

Most of our arterial roads in Bombay have already been constructed and they have been constructed on cement concrete foundations. In residential areas it is found that even a 4″ cement concrete road has given satisfactory results. In the case of new roads in residential areas, where ordinary macadam roads were formerly constructed, cement concrete roads have now been laid and the levels on curves and footpaths are so adjusted that should the concrete road prove unsatisfactory a wearing carpet of asphalt is laid over it so as to give additional strength to the road. (Applause.)

Khan Bahadur M. Z. A. Faruqi: Gentlemen, we are much indebted to Mr. Turnbull for the vast information contained in his paper, which is bound to be very useful to us. There are just a few points which I want the writer of this paper to clear up. These are as follows:—

In paragraph 2 of his paper, Mr. Turnbull says:—"As in every other problem of structural design, the designing of a concrete road resolves itself into first, a decision as to the forces which will act on it, and second an economical aspect of the design that will resist these forces." As to the latter part, I would be much obliged if the writer will kindly let me know the name of the authors of such books as have dealt with this aspect of the problem. To my mind, this problem has not been thoroughly dealt with anywhere; our conditions of traffic are so varied. If there is any work which deals with this, and he will kindly let me know, I should be much obliged. Our problem to-day in India is to have a cheap road, which will

be an improvement on the old waterbound macadam roads and which will avoid dust. For work of this nature, some advocate bituminous construction the cost varying from Rs. 12 to Rs. 24 per 100 square feet. In the sections recommended at the end of paper No. 8, the minimum thickness is 5 inches. I think a section of this size will cost something like Rs. 50 per 100 square feet. This will not meet the situation. I wish the writer of this paper had included some experiments on thinner roads in India. With the permission of the Chairman, I would like to mention that the Public Works Department in the United Provinces tried experiments of this nature about the end of 1931. The main objection of the engineers and other officers concerned was about the financing of these thick concrete roads. They were of the opinion that concrete roads were very good; but being very expensive people could not afford to invest money on them. In 1932, various lengths ranging from 100 to 200 feet, were laid on an approach to Lucknow City. This was about three miles away from the city. The original road was of kanker, width 12 feet, and the traffic was about 500 tons per day. Various lengths were laid, not only of different thickness, but of different strength of concrete used by varying the proportion of cement. Today, more than 2½ years have passed, and the 3-inch slab with a mixture of roughly 5·15 cubic feet to a bag of cement at a cost of Rs. 2-13-0 is standing well. It has to be seen how long it stands further. So far, the surface of that particular portion, though it is cracked, is perfectly sound.

In paragraph 6 of the paper various methods are suggested for improving the subgrade. We all think that cement concrete roads are very nice, but I suppose very few of us are aware how the cement concrete roads break. Of course, Mr. Hari Chand and Mr. Hunter know about this. There is a cement concrete road between Moghal Serai and Benares which is now about 8 to 10 years old. It has cracked just in a few places, longitudinally, not transversely, more or less for about a mile. It is just possible that this is due to subsoil water passing underneath. At one place, particularly, where the road passes through a shallow tank, and where the bank is made more or less of black cotton soil and water stands on either side, when water is stored for agricultural purposes, there is a through crack in two-furlong length,—longitudinally and varying from about ⅛ inch to about ¼ inch width. I would be interested to know if the writer of this paper could suggest a solution. I am no longer concerned with this: but I would like to know this for my own information. It shows that we have to be cautious. The road is 20 feet wide and the crack is in two-furlong length. It is not very straight. There are one or two other places where the drainage is passing underneath and there are cracks. The cracks did not appear for the first or second year, but they made their appearance in the third year, showing strained condition just like when you take a fresh piece of India rubber and try to bend it. I must mention, in respect of all these cracks, that the surface is perfect strong and smooth. The most striking part of these cracks is that they are all longitudinal, except for two or three transverse cracks.

In paragraph 19, the author has mentioned about fatigue. I would be glad if he would recommend some exhaustive work on the design of concrete roads, because to my mind, the question of fatigue does not come much into practical working at all. All the designs here are for America and there the cross-sections, except for the top one which is specially meant for some special traffic, are for cars and trucks without any mention of the

loads. They have varied thickness just in proportion to the intensity of the traffic. Does it really mean that this variation in thickness is for the taking of the fatigue?

In paragraph 21-A, figures are given for the expansion of cement concrete. It roughly amounts to one inch in 100 running feet, or for a length of 33 feet, it will be ⅓ inch. My experience is that these widths of 1 inch in 100 feet, or 1½ inches in 150 feet, are not worth troubling about, because a slab of 100 feet does not shrink but the strain is caused by the reduction of the temperature. They shrink just by a paper thickness or a card board paper thickness on the outside. They do not shrink in proportion to the theoretical shrinkage calculated according to this or according to any other formula. So, what actually happens is that concrete remains under strain and by introducing this joint we relieve about 10 feet length in the immediate neighbourhood of that particular joint. The writer has recommended certain materials for joint. These joints are likely to give trouble in their neighbourhoods. In the paper on Hyderabad roads you would have noticed that there is definite mention that they do not introduce any material in the joints for the purpose of taking up the expansion and contraction. In the United Provinces, bitumen joints were introduced more or less purely as an experimental measure or on account of the coaxing of some agents. All the roads have been built by butting one slab against the other, whether they are 33 feet or 40 feet long and the two slabs have tried to expand and contract. When an expansion point is put in, it is open to so many complications. In hot weather some of them run out and you have to fill in new material or else some of it gets under the concrete and in the hot weather it bursts the concrete by melting. These joints, which have been made so much of, and for which so many specifications have been issued for use in India, should be completely forgotten. That is my view, and I suppose the roads which have been standing for 8 years will prove that I am correct. None of these materials should be put in to take the expansion and contraction. Of course, the slab will relieve itself of the stress caused within about 8 feet. On that principle, originally, when the construction was started in Benares, we brought down the length of each bay to 16 feet. But the joints, however nicely made, are not a pleasant thing to introduce. We adopted bays of 30 feet, then 40 feet, and after that, we made another stretch of a two-furlong road on an embankment near about Cawnpore with 60 feet bays, and it has worked well. It is for consideration whether we really should pay so much attention to this point, although in practice this has not been done.

There is mention of longitudinal joints. We here in Delhi have also put in longitudinal joints. What is the advantage of longitudinal joints? I would request Mr. Turnbull to tell us about it. Is it worth while breaking a width of 20 feet into two strips of 10 feet each and then to prevent it from moving about by putting in bays? Why all these complications? I should think that we should not introduce from the beginning anything which was likely to be taken by the iron tyres of the traffic. These metal pieces which are put in occasionally in the construction of the concrete joints are not really worth troubling about, and many possibly create trouble themselves. There is a mention in Mr. Zeman's paper, about the joints being placed at an angle of 6 degrees to the longitudinal axis and that they have given it up. I think it was Col. Walker who read a paper in England about 1926. He advocated interlocked joints so that the two slabs will

work in conjunction with one another, distributing the loads half from the top and half from the bottom. These joints were tried and proved very complicated. In the diagrams appearing after page 228, every section is proposed with a tongue and groove joint. What is the function of these? I would request the writer to let me know.

On page 227, some mention is made about the constructional details of these slabs and a summary of finishing operations as applied in most of the other countries. At the end of this paragraph it is said, "Too much tampering or any over-finishing which brings much mortar to the surface, seems to be responsible for most of the surface scaling, and should be guarded against." In this connection I just want to give a word of warning. We should aim at keeping the water ratio at the minimum. If we put in more water, it will work as a lubricant, drawing up the cement to the top.

So far as cement concrete is concerned, we should try to minimise the cost of construction by putting 1 inch to 2½ inches lime concrete. If anybody wants information, I can give it.

Mr. H. Hughes: Mr. Chairman and Gentlemen, although the papers we are discussing are on concrete roads in India, yet I should like to refer to the concrete motor roads now being constructed in Germany. Sections of the German national motor road were shown to delegates of the VIIth International Road Congress which recently met at Munich. The general design contains points of universal interest. but I fear that most of the things that are being done there are much too costly for anything that can be attempted in this country at present. The general design is formation width, 80 feet. On this are laid two roadways, each 24 feet wide, for one way traffic. The road is intended for motor traffic only, and so there is separation of grade at all crossings with other roads. Where a concrete design has been adopted, the slab is laid in two courses. The bottom course consists of stone of about 1¼ inches and the proportion 1 · 3: 5, thickness 7 inches. The top course consists of stone of about ¾ inch size laid in the proportion of 1 : 2:3 and of a thickness of 3″. The minimum curvature is 1¼ miles super-elevated for a speed of 100 miles per hour—they are looking well to the future. The interesting point in the design is the cross joints. They are provided at varying intervals of 41, 49 and 57 feet. This arrangement is obviously to avoid any uniform rythmic corrugation.

Mr. R. G. Burt: Mr. Chairman and Gentlemen. it appears that one of the draw-backs of the cement concrete road is the time for which the road must be entirely closed. I would like to ask the authors of these papers and also any other delegate present if they can give us any information about the use of road hardening cement and its effect on reducing the time that a road has to be closed, and also its effects on the life and behaviour of the road. This draw-back of the road having to be closed very often may rule out the use of concrete roads where the diversion of traffic is undesirable or impracticable. I think that we would like to have information on this point of the use of road hardening cement. Information might be collected on the point and further experiments might be beneficial.

Khan Bahadur M. Z. A. Faruqi: I was carrying on construction with ordinary cement until 1930 and then it was remarked that this type of construction took a very long time and that it meant blocking the traffic for a good long time as the preparation of the sub-grade took about fifteen days and then after that four weeks were taken for curing it. The whole needs a little more supervision and one has to be very careful with rapid

faster. By systematising, we did manage to reduce the time spent in the preparation of the sub-grade. We found that by the use of a rapid hardening cement, the quantity of cement was reduced by about ten per cent. The strength of the concrete was the same as claimed by the manufacturers and there was a saving of about three weeks in the time for curing. In all it meant a saving of a month and as to the cost of construction there was no difference. This, *i.e.*, the construction with rapid hardening cement needs a little more supervision and one has to be very careful with rapid hardening cement. Those who do not know India may say that the labour in India is worthless. But Indian labour can be very well trained. But one thing to be constantly impressed on them is that *we cannot go on working on cement* for hours. Inside the cities, we cannot afford to block the roads for any length of time and for such places I would suggest the use of rapid hardening cement which will save a great deal of bother to the Engineer in charge. The quality of the cement concrete road is perfectly all right and those who have been on such roads cannot notice any difference.

Mr. A. Vipan: In Madras cement concrete has not yet been used extensively for road construction. It has been used for the decking of bridges. In certain cases we found that the cement concrete breaks up to some considerable extent. I should be glad to know if this has been the experience elsewhere. We should like to now whether this is due to vibration or some other cause. As regards cement concrete roads in cities, it appears to me that this is ruled out entirely in such cities as are contemplating drainage and water supply schemes.

Mr. D. Macfarlane: Mr. Chairman and gentlemen: We heard a short time ago with great interest the description of a road in Germany where the super-elevation is designed for 100 miles an hour. You probably all remember Sir Jogendra Singh's speech* at his lunch party in Lahore where he pointed out that our principal enemy in this country is the Finance Department. Sir Jogendra Singh pointed out that all our activities depended on the question of finance. On this tour I noticed particularly that many of the delegates raised their eyes of horror at the cost of some of the types of roads, and said that they could not simply afford them. Roughly speaking, a cement road costs something in the region of four times an ordinary road and I think that for most of us the only thing that can ever come within the range of practical politics is the widening of the more heavily trafficked roads with cement tracks at the side and it was for that reason that in your tours in Lahore we took you to the Multan road and showed you there our proposals for widening that road. In connection with that particular work I had a most interesting discussion with Mr. Turnbull and with Mr. Mitchell, who is going to finance the work to the extent of 50 per cent and the interesting part of the discussion related to this question of the sub-grade over which a lot has been written in these papers. When you are reconditioning an existing road, it is one matter but when you are widening an existing road, it is an entirely different matter and to my mind it is an extremely difficult one. In the case of the Multan Road, we have got a fairly high embankment. Our problem is to put this cement track on the outside and the question is whether we are going to increase the thickness of the outer edge of the concrete or to provide an adequate sub-grade which will be pretty high. We have not yet decided how exactly we are going to solve this

* Pages 272—273.

problem but this is an entirely different problem to the one of putting a cement road on an already existing surface. We have been discussing just now the inconvenience to traffic by the putting down of a cement road and the discussion went on to the question of using quick hardening cement. In the case of a track such as the one to which I now refer, I wonder whether it would not be possible to put up pre-cast slabs. On the Chenab bridge which you also saw on your tour, we did the decking entirely with pre-cast slabs which were six feet long and three feet wide and there is not very much difference between six feet and seven feet.

(Mr. Macfarlane then illustrated his points on the blackboard.)

Mr. D. Daniel: Paper No. 8 sets forth clearly and succinctly the latest practice in the design and construction of concrete roads. Though there is practically nothing to comment on these specifications. yet I was only wondering why no mention was made about the application of silicate of soda recommended by the Concrete Association and advertised by the firms dealing in them. I hope Mr. Turnbull will give us his opinion on the same.

Also the diagram appearing after page 228 looks to me as though it is not quite correct. For example 9″ slab for a modulus of rupture of 300 pounds can carry a wheel load of about 8,000 pounds according to the formula given; whereas from the diagram we get a low figure of 3,800 pounds. I think it requires some explanation.

Gentlemen, I find that there is an important matter to be gone into by a body like this Congress, in connection with the design. The International Congress has given a formula which has also been referred to by Mr. Turnbull where W is the maximum wheel load. On referring to the diagrams at the end of his paper it is seen that the thickness is varied according to the volume of traffic. One should have expected the thickness to have been designed on the above principle and the width varied according to the volume of traffic. Again in Delhi a slab of 7: 5: 7 is laid. In Hyderabad, 9: 6: 9 is laid. On the Nasik road, 6: 4: 6 is laid. None have stated for what load they have designed their slabs. If it is for a 10 ton roller one wheel-load is about 11,500 lbs. including 30 per cent, impact and the slab will be $10\frac{3}{4}$: $7\frac{1}{2}$: $10\frac{3}{4}$. If the slab is 9: 6: 9 it can bear a load of about 8,100 lbs. including impact of 30 per cent. This means that lorries of $3\frac{1}{2}$ to 4 tons capacity weighing about 7·5 tons laden can be carried by the slab. It is therefore a matter for consideration whether the concrete slab will have to be designed for the occasional heaviest load or for the average traffic units. As the high initial cost for a heavy section may not be justifiable will it not be sufficient to allow such heavy occasional loads to be taken care of by the factor of safety allowed in the design? If the occasional heavy load can be disposed of in this way what is the average traffic unit for which we have to cater for? These are matters, gentlemen, that will have to be decided by you sooner or later.

In Paper No. 9, it is stated that cement concrete has been laid to a breadth of 19 feet in the middle and the sides were paved with a lean mixture of lime concrete. One would expect it to be the other way since the slow country cart traffic uses only the sides. I should like to be informed whether conditions are different in Hyderabad. In paragraph 16, the advantages of cement concrete road over the asphalt roads are given. The first two reasons seem to be open to some controversy. An asphalt road does not always require the foundation indicated.

If the old crust available is about 9 inches, it is reformed with a thin coat of new metal and the asphalt laid; the figures given under item 3, therefore, requires some alteration. Also a concrete road takes nearly 28 days for curing unless it is rapid hardening cement, whereas traffic can be allowed over asphalt pavement after 4 or 5 days at the utmost. So I could not understand how the reasons adduced here against asphalt could be upheld. It was also stated that a cement concrete road could be constructed at less inconvenience to the public and in less time as compared with the asphalt road. I think it is just the reverse.

In Paper No. 7, in paragraph 4, it is stated that 6 feet width is given for slow traffic and 7 feet 6 inches in the middle for the fast traffic. I should like to observe in this connection that the generally accepted widths required for such traffic including the clearance required according to their speeds are 8 feet and 10 feet respectively. Anything less than this is likely to prove dangerous to the traffic at times.

The conclusion in para. 17 of the paper No. 9 seems to be open to controversy again. It is not always possible to find funds for concrete roads everywhere. A concrete road will be a necessity in short lengths of main trunk roads within town limits and their outskirts. Further short lengths adjoining the towns may have to be paved with two concrete sides with an asphalt pavement in the middle. Even if the original width is 12 feet, it will be advisable to segregate the steel-tyred bullock cart traffic as above. For other important sections surface painting may be required chiefly to allay the dust. These are the improvements, I am able to visualise, that will be required for our main trunk roads in the near future. Hence I do not quite agree with the conclusion of this paper and the conclusion arrived at in para. 25 of paper No. 5 (b). Nor do I agree with the conclusion arrived at for heavy bullock-cart traffic in para. 97 of paper No. 6.

I thank the authors of the papers for having kindly placed at our disposal their valuable experiences in the construction of these concrete pavements.

Mr. S. S. Bhagat: Mr. President and gentlemen, I am not going to read all these papers and I hope what I have to say will not be very boring. I must congratulate Mr. Greening for his very interesting paper and it is of great interest that this method was tried in Bombay. I must say that this method, when it came out, did not appeal to many as they thought that it would not be suitable for heavy traffic or medium traffic. It seemed the results in Bombay showed that it could never be satisfactory but that it is just possible that it may do better in localities where traffic intensity is not so severe. There can of course be no doubt that it cannot be expected to compare equally with cement concrete. In these papers some doubts were expressed about the slipperiness of the cement concrete roads. I do not know why these apprehensions should have arisen because in the United Provinces cement concrete roads have been under traffic for the last seven or eight years and no complaints of slipperiness have been received so far. I must congratulate Mr. Zeman for his excellent paper and his well-reasoned arguments in favour of the

construction of cement-concrete roads in Hyderabad. We in the U. P. have found by actual experience that nothing but cement concrete roads would stand under heavy traffic. We did not take traffic censuses in those days and I cannot give the figures but gentlemen you will perhaps be interested to learn that in Cawnpore in 1925 two miles of asphalt concrete (premix) were laid and after about 18 months' traffic they gave way and cement concrete had to be put in. It is standing up well up to now. In Allahabad both T. R. A. and mexphalt grout were used in two miles in 1926 and after about nine months' traffic both these miles gave way and cement concrete had to be used to take the traffic and both these are still standing well, so far as I know. Mr. Zeman mentions an alternative bay method of construction. He says that an interval of five days was given. It seems that this interval was rather short, unless rapid-hardening cement was used, as it would hardly give time for the cement to set and the real reason for using the alternative bay method would be lost. Mr Zeman has not mentioned how they mix the aggregate in Hyderabad, as we found that hand-mixing was not so good or economical as the mechanical mixers and the other advantage in using the mechanical mixers was that the water ratio could be controlled much better and satisfactorily, which probably is an important factor. The cement concrete experts will probably advise us in the matter. Mr. Zeman has also mentioned that a central joint should be provided. We found that such a joint was not satisfactory both as regards construction and when the road is actually in use. The joint goes on widening due to wheels of carts etc., always getting into it and there is always trouble in filling it up and keeping it in good condition and this joint should be avoided as far as possible. Probably the cement concrete experts will give us their opinion. It is also mentioned that cement concrete can be laid very rapidly, but that is not very convincing as the sub-grade and the actual laying of the concrete and curing takes from a month and half to about a month and three-quarters before the section under operation can be opened to traffic. Of course the time can be considerably reduced, as has been mentioned by one member, if rapid-hardening cement is used. I quite agree with the authors about the advantages mentioned in the papers in using cement concrete but we can not have it for each and every road as the initial cost is very high; it can only be justified wherever a cheaper method of construction will not solve the problem. The mixture given by Mr. Zeman appears to be too rich. I do not know how they arrived at the proportions stated in the paper. In the United Provinces we generally use one to four and we have found the roads most satisfactory so far. Perhaps the Hyderabad people will find that their roads will last longer than ours.

A question was asked about the use of rapid-hardening cement. It was actually tried on crossings and the slabs were opened to traffic after seven days only, which shows that a lot of time can be saved in any localities where it is necessary to use it because the cost is not very great and it is found that the time can be reduced considerably. Some remark was made about the use of cement concrete in localities where there are difficulties about drainage and water pipes. I think in some localities this defect could be solved if the pipes etc., were laid on both sides, so that they are not connected across the road especially in places like Delhi where I believe, they are going to do cement concrete in Chandni Chowk. If that is correct, then in other places also they can do so. Mr. Macfarlane mentioned something about the cost of providing cement concrete roads. It is quite true that cement

concrete is more expensive, but if actual figures are gone into, it will be found that in the long run it is not so very expensive. There was a long stretch of road in the United Province which was to be re-constructed and we worked out the figures and we actually found that in ten years' time a cement concrete road would probably cost about just the same as stone metal and surface painted and that in fifteen years' time it was possible to save about Rs. 25,000 from the maintenance cost alone, as the cost of maintaining cement concrete is very small and painted surface requires a considerable amount In their case it will be about 3 annas per sq. yard annually. We also worked out that from savings of maintenance the whole length of a road could be re-cement-concreted in 30 years and still save some money.

Major W. B. Whishaw.—Talking about rapid-hardening cement, it may interest you to know that all the bridges and culverts and the bulk of the Irish bridge work which you saw on the Mohamand road were all done with rapid-hardening cement and were opened to traffic subject to the road being up to that point within forty-eight hours. As far as I know they have not given any signs of trouble whatever. (Applause).

Mr. B. F. Taylor: I would like if I may to put a conundrum and I must apologise for raising yet another question. I should like to ask Mr. Turnbull if he can explain what has happened in Assam, where, as in the case of Madras, about which Mr. Vipan has just spoken, our experience of cement concrete has so far been confined to bridge road-ways. Last cold weather and the cold weather previously we put down a large number and on certain of them, to assist curing and hardening we used silicate of soda. I notice Mr. Turnbull in his paper advocates water-curing only and we will certainly stick to it in future. I should like to tell him what has happened to silicate of soda where it has been applied to cement concrete bridge roadways. A curious crystalline deposit has appeared on the underside of the concrete. How has it got there? It cannot have gone through the concrete. We can only assume that it has worked its way between the concrete and the curb plate than along the inside of the plates and has appeared through the joints. At present it is showing an unpleasant-looking and a very ominous-looking crystalline deposit. Whether or not this is causing corrosions we cannot yet say. I should be very glad if Mr. Turnbull can tell us why it is so, and what it is.

I apologize again for asking these troublesome questions. I should like to mention the question of crete-ways. To Assam a small grant was made three years ago from the Research Fund to try crete ways on an ordinary earth road. We have done so and they have been a complete success. Four and a half inches of concrete was laid in trenches dug in the road. The object of our crete-ways is not as in the Punjab to take bullock carts and to leave the rest of the road for fast traffic but to take all traffic when the remainder of the road is a morass. We want, if we can, to get a further grant to try this out on roads under different conditions throughout the Assam Valley and I hope that the technical sub-committee which it is proposed to set up to advise on research will allow us to make further experiments with these crete-ways in different forms and under different conditions. (Applause).

Diwan Bahadur N. N. Ayyangar.—We have had a discussion on these roads for the last so many days and our problem as I told you was to find a dual purpose road. These various types are all very well for municipal areas and also just near towns, say within five to ten miles outside the towns and also in special places. Our problem generally is of rural roads and the maintenance amount that we get is very little indeed. It varies from Rs. 300 per mile to Rs. 500 per mile, whereas the circumstances in the Punjab and the N. W. F P. have been such that the ordinary maintenance cost has been very great, say Rs. 1,700 a mile per year.

With ordinary tar the cost of maintenance has been reduced to Rs. 1,000 and that would be required for the periodic repainting of the surface with tars or emulsions or bitumen surfacing. But we cannot ever hope to get all that money in other provinces and for carrying out these works we will have to do it out of loan funds and again the maintenance also will be very costly. Therefore we are tied down to our old macadam roads. Up till now we had only the bullock carts and nobody complained for the last 100 years about the destruction caused by the bullock carts to the roads. As referred to yesterday, motor traffic naturally causes corrugations, which is the characteristic way in which ordinary macadam gets worn out under mechanical transport. The corrugations are indeed nothing but a series of shallow pot holes. Now to have a continued use of macadam on our ordinary rural roads, we have to strengthen the surface of the macadam roads.

The other important point is the sub-grade. If both the surface and the sub-grade are reasonably good they would stand motor as well as bullock cart traffic. We are doing the surfacing with tar and bitumen. Cement is a local material and we want to use it for our macadam roads as much as possible. Its use as slabs is very costly. I suggest that cement should be used in places where the maximum strain comes under motor traffic. What I suggest is that we make an ordinary macadam road in the usual way, and after we water and roll it thoroughly instead of putting blindage, we should use a mixture of say one cement and two of sand in and then sweep it into the interstices of the macadam and just get a mosaic effect in the final result. There should be no surface skin. This cement would be able to take the abrasion just as the tar or bitumen does. This I wish to suggest for further research because the macadam that failed in Bombay was due to the sandwich method. There unfortunately cement was put below the surface and in the body of the metal where there was no strain at all. It has to be at the very surface where the maximum strain due to the abrasive action of motor vehicles comes. I wish to suggest that a certain length of road may be tried on these lines and with Mr. Mitchell's help, I hope to be able to make an experiment. Yesterday there was a proposal for having a research scheme. It would take time to bring it into existence. I will be prepared to carry out that experiment and I will report the result before the next Congress.

Mr. H. A. Hyde.—Mr. Vipan asked a question about the cement concrete being used in the construction of bridges and said that the cement concrete breaks up to some considerable extent. We have

numerous submersible bridges in the Central Provinces and formerly we used for their paying nothing but stone, excellent stone hard black basel. I have recently abandoned stone in favour of cement concrete because I get a much nicer surface and our experience in most places is that it is standing up to the traffic very well indeed.

Mr. A. W. H. Dean: Mr. Chairman and gentlemen, I have got nothing to contribute to this discussion except a few questions. The longitudinal joint in a cement concrete road has been adversely criticized by some. I am not at all clear as to what Mr. Turnbull—I think probably he is the one authority in India—really thinks of it. But it seems to me to have certain merits from the point of view of construction. For instance you can construct half your road at a time and you do not interrupt the traffic and again due to the thickening of the two separate sections at the edges it seems to be scientific from the point of view of carrying two separate lines of traffic. We have been putting down 7: 5: 7 in one width across the road and also in two strips with a central joint. The latter has the apparent advantage of giving four thicker edges to take the wheel load of each line of traffic.

The next question I would like to ask is what is the best type of expansion joint, that is to say, what is the best position for it. The most obvious of course is right angles to the direction of the road, but this is distinctly unpleasant for traffic. You get your two front and rear wheels going off and on to each slab at the same moment and so get very much more of a jolt than you would with a diagonal cross joint. On the other hand that would tend to introduce very weak triangular pieces at the edge. We have tried putting down joints which are diagonal across the central strip and then turn at right angles to the edge for the last couple of feet I am not sure if that is a good thing or not.

The next point is about the hexagonal surface reinforcement. I read a description of it some few years ago in an American paper and I first tried it out in a concrete flooring of a squash court. Strips of hoop iron, one inch $1\frac{1}{4}$ inches wide and $1\frac{1}{8}$ inch thick, bent into a hexagon of 20 inches diameter were laid just about half an inch below the surface and we laid the whole of the court without any construction joints and in three years it has shown no signs of cracks other than the finest hair cracks. I have tried it in a submersible road bridge where we laid a cement concrete floor putting it down in strips of 132 feet. The design was a continuous beam of four spans of 33 feet and we made our surface construction joints coincide with the construction joints of the reinforced slabs in the bridge and there also we found that we got no cracks at all. I recently used it in a road and within about two months I got some very unpleasant looking cracks in the middle of the length laid with hexagonal reinforced construction. I am not sure whether these cracks are due to the sub-soil. I want some comment on this point if possible.

The next important point in the use of cement concrete for roads is the use of the minimum amount of mix water. I myself am rather doubtful about this as I have found cases where I had rather unsatis-

factory concrete and on investigation I found it was rather honey-combed. I am inclined to the opinion and I want some comment on it by others—that a slight increase of mix water, although it undoubtedly reduces the strength of your concrete if you are getting it mixed to the maximum possible extent, actually makes a slightly more workable mix and in our ordinary work gives more satisfactory results. The loss of strength in honey-combing in very dry mixes is more than sufficient off-set the increased strength that the concrete otherwise obtains. With regard to the cement, sand, aggregate ratio. Some people have given 1-2-4, others 1-2½-5 and so on. I would be interested to know if any one else has had my experience which is that you never get the densest mix of any sand and aggregate if you proportion them definitely as 1—2—4 or 1—2½—5. The densest mix is important. I have locally found here that 1—2½—3½ is generally a much denser mix than 1—2—4 using Delhi stone and Badarpur Sand.

Mr. Macfarlane speaks of pre-cast slabs. We have tried pre-cast slabs on bridges and the difficulty is the enormous number of joints that are involved in the surface because there is, a limit to the weight of a pre-cast slab. Otherwise pre-curing is undoubtedly much more effective than curing *in situ*. The test of a pre-cast slab gives almost invariably higher results than the test of concrete cast *in situ*. But the limit of weight for a slab is important as involving such a large number of joints that the resulting road surface is really rather uneven.

I would like some further information on rapid hardening cement. At the time of initial set, do you have to exercise any very special care in using rapid hardening cement from that point of view?

I would particularly like to ask the Hyderabad Engineer who has been putting down cement roads how does he make a cut and how does he fill it in? It seems to me that unless you are going to lay down a whole series of tunnels for all your services, cables, water pipes and so on, it is almost an impossible situation to have cement concrete roads in a city.

Mr. G. Reid Shaw: Mr. Chairman and gentlemen, we in Assam, had some difficulty in reducing our floor loads on bridges, and we had a case a few years ago of a very long suspension bridge on which we desired to reduce the floor load. Now, the weight of concrete on that bridge was nearly as much as the steel work. If Mr. Turnbull would give us a specification for a light concrete, we will be able to make an enormous saving on our designs of such bridges. In the case of that bridge, we tried a coat of coke breeze concrete, and the engineer who was in charge of it described it in language which I cannot describe to you to-day. If the author of this paper could give us any assistance on that matter, we will be most grateful.

Mr. K. G. Mitchell: Mr. Chairman and gentlemen, I think it was Khan Bahadur Faruqui who suggested that more attention ought to be devoted to thin concrete slabs, and it has been a practicable proposition particularly when used on old established macadam roads. I suppose he will agree that with the exception of a few roads, we have laid them on old macadam roads. We have, I think, been influenced to a great

extent in this matter by American practice, in fact, Mr. Turnbull has given us very typical examples of American practice of laying concrete roads on mother earth, but our conditions are very different, and I think possibly we are inclined to be rather extravagant. Mr. Hughes told us that new motor roads in Germany are costing 10 lakhs a mile. Of course we find it difficult to believe. The Glasgow-Edinburgh Road, I think, cost Rs. 60,000 a mile which is not very far off from that. I rather feel that if we take old macadam roads and then put a heavy concrete surface at the top, that would be extravagant, and I think we should try thinner sections.

I would like to ask Mr. Turnbull another question. He mentioned the alternative of laying some fabric below the surface. That has always been a difficulty with me. Mr. Bhagat, again, to-day quoted figures to prove that in the United Provinces their concrete road is no more expensive than the various other alternatives, and said that in 15 years it showed a definite advantage, but the difficulty is, what do you do when the concrete wears out. If you want to make an estimate of the economic value of the concrete road, how do you estimate the renewal, and what thickness of concrete do you propose to put on, because, after all, sooner or later, it must be done?

There are one or two other small points which I would like to mention. One of the objects of this Congress is to know what is a success and what is a failure. Diwan Bahadur Ayyangar asked me if I proposed to help in financing an experiment with cement on macadam roads. It seems to me that the general experience is that "cement sandwich" method has not been a success. I know of one or two roads in the neighbourhood of Nagpur which were laid on by the Municipality which are a success, but on the whole as far as I know, cement macadam roads have not been a success.

Diwan Bahadur N. N. Ayyangar: What I suggest is altogether different from the sandwiched method. That is the reason why I suggest an experiment. Anyway, if Mr. Turnbull could tell us what percentage of cement macadam roads has been successful, we shall be glad.

I believe some time ago the trackways were laid in Jubbulpore, but they were not a success. I think we ought to record whether the trackways and cement macadam were at all successful. I found unsuccessful we can eliminate these two methods and a good deal of further unnecessary experimenting will be avoided.

Chairman: Gentlemen, before asking the authors of these very valuable papers to reply to the criticisms and questions asked, I should like to say just one or two words. I should hate to sit down without seizing this opportunity of inviting your attention to the fact of our "fairy God-mother", to use the Hon'ble Sir Jogendra Singh's own words, in appointing to the Chair to-day to consider these Papers a representative from a province which, through its stress of financial circumstances, has been unable to embark upon the construction of any concrete roads. It follows that I should be or ought to be brief in my remarks and not detain you for long, and also that I should have an unbiased mind in this matter. In Burma our official acquaintance with concrete roads has not got beyond the stage associated with a "watering at the mouth" whenever the subject is mentioned. In so far as the road surface of bridges is concerned,—and here regrettably I must associate myself with the remarks of Mr. Vipan and to some extent with those of

Mr. Taylor also: we have sometimes used cement concrete for filling the troughs and providing the travelling surfaces but in many cases we have had unsatisfactory experience. The surface has gone to pieces under the destructive effect of steel tyred carts. In fact, in order that we could have some idea as to when it was necessary to renew the surface of the concrete road, we placed a fairly small mesh wire netting about 1½ inches from the surface so that this might be exposed when we were coming to the danger line in the slab. This is somewhat similar, I think, to Mr. Turnbull's suggestion of putting down canvas. Personally, I attribute the failure of the bridge floors to bad workmanship or bad materials. Very likely it is often due to improper curing. There are two or three rather serious objections to the extensive use of cement in Burma. The first lies in the fact that cement has a very high market value owing to the passion which the indigenous population have of using it in the construction of pagodas. It therefore follows that whenever you use cement it is essential to maintain an adequate staff to supervise the work in order to see that the cement shall go into the work and not into the market.

Another point is our difficulty with sand. I think this is a matter which is sometimes not appreciated by the men actually in charge of construction work. Recently one of our officers took many samples of Burmese sand to England in order that they might be tested under ideal conditions. If my memory does not fail me, I think the results of many of these tests made with the Burmese sand showed that the samples were frequently as much as 30 per cent. weaker than samples made with standard sand. It therefore follows that it is essential to take the utmost care in selecting the sand when you are considering the construction of large or even small concrete works.

Now, I would ask the authors of these papers kindly to come forward and answer the questions which have been raised.

Mr. L. E. Greening (Author of Paper No. 7): Mr. Chairman and gentlemen, Mr. Daniel raised the point as regards the width of the central portion between the creteways as being 7 feet 6 inches and considered that it seemed to be rather too narrow. Actually in the original plan the central width was to be 6 feet. Fortunately before the works were put in hand it was discovered that road roller could not work on a width of 6 feet and so it was increased to 7 feet 6 inches which is the minimum width required. That is all I have to say, Sir. (Applause.)

Mr. Chairman: Will Mr. Turnbull kindly come and answer the questions that have been put this morning?

Mr. W. J. Turnbull (Author of Paper No. 8): Mr. Chairman and gentlemen, it will take me a considerable time to answer all the questions in detail, and I suggest that with your permission this might be carried on by correspondence. During the time available I propose passing a few remarks on the following points. The question of the high cost of concrete road has been raised and in this connection I may say that in Bombay we have carried out some experiments on thin concrete road slabs. I would like to describe to you briefly the methods employed.

One of the advantages of concrete roads lies in the fact that if properly designed it does not require a base, and can be laid directly on almost any subgrade so long as it has a uniform bearing.

Most of the concrete roads in India are laid on old well consolidated waterbound roads and it has long been felt that it might be possible to utilise this existing waterbound macadam so as to make use of a thinner concrete slab than is customary; in other words, to make a thin concrete crust act in conjunction with the old base. In order to investigate this problem experiments were carried out in Bombay about a year ago on a short length of road carrying a traffic weight of about 100 tons per yard width.

The existing road had about 9 inches of soling with approximately $1\frac{1}{2}$ to 2 inches of metal and the following procedure was adopted in the construction:—

Preparation of the Base.—The surface of the old water bound macadam was wire brushed and thoroughly swept free of all blinding and loose particles so as to leave the metal protruding.

As far as possible this brushing and cleaning was done with the surface in a dry condition. Any deep pot holes or ruts were filled in with metal to economise in concrete. The sides of the road were trimmed to give a depth of 3 inches of concrete, reducing to 2 inches about two feet from the edge. This is done to strengthen the sides.

The forms consisted of one line of brick on flat laid with a 1.8 cement mortar. The construction of the brick forms was carried on well in advance of the concreting operation and great care was taken to see that they were laid to the correct line and grade on each side of the road.

The next operation was that a 2 inches wire netting No. 16 gauge was placed on the clean macadam and fixed in position with nails at about 3 feet centres, so as to be approximately in the centre of the 2 inches concrete surfacing. The wire netting was lapped about 4 inches at every junction and secured with wire ties. A neat cement grout of the consistency of thick cream was then brushed evenly over the surface of the protruding macadam in order to bound the concrete with the existing metal. This application of cement grout is exceedingly important as it ensures the bonding of the crust to the existing metal. This cement grout should never be more than two feet in advance of the concrete, otherwise it will dry out and be ineffective.

Meanwhile the concrete was mixed ready for use in the following proportions:—

1 part of cement,

3 parts graded sand,

4 parts broken traps graded from $\frac{3}{4}$ inch to $\frac{1}{4}$ inch,

$5\frac{1}{2}$ gallons of water per bag of cement.

Several trial batches had to be made in order to adjust the ratio of the fine to the coarse aggregate in order to produce a readily workable mix. The concrete was then deposited to an approximate thickness of 2 inches and at no point was the thickness less than $1\frac{1}{2}$ inches. The concrete was then brought to the required contour by means of a wooden tamper fitted with handles. This was shaped to the cross section of the road and strong enough to retain its shape under working conditions. Curing was subsequently carried out in the usual way.

That is briefly the method employed and the experimental length has now been in service exactly 13 months. Actually we carried out four different experiments, one with No. 9 B. R. C., one with 3 inch wire mesh, one with 2 inches wire mesh, and the fourth with hessian or canvas. The section with No. 9 B. R. C. has cracked very badly; the 3 inches mesh has six transverse cracks in 100 feet; the 2 inches mesh has two cracks at about 35 feet intervals while that reinforced with hessian is a failure. The cost of the type of road I have just described is approximately Rs. 18 per 100 square feet in Bombay. Where a well consolidated waterbound macadam road is in existence, it is possible that thin lightly reinforced concrete surface may be an economical solution where wheel loads are not excessive.

Diwan Bahadur N. N. Ayyangar: What about my suggestion?

Mr. W. J. Turnbull: I do not know whether your suggestion would work. It might be worth trying.

Diwan Bahadur N. N. Ayyangar: For general use, for lighter work it is the only hope.

Chairman: Mr. Turnbull will reply to the other questions raised by correspondence.

The following was communicated by Mr. W. J. Turnbull by correspondence:—

A Reply to questions raised by correspondence.

Mr. W. B. Gunnell, Chief Engineer, Ford and Macdonald Ltd.—The writer has read this Paper with interest and thinks that it would be of use if Mr. W. J. Turnbull gave recommendations as to the grading of aggregate which he considers best suited for different thicknesses of pavements. A certain amount of uncertainty seems to exist amongst engineers regarding this point and it would be of interest if figures and facts could be given showing the density and strength of concretes using different gauges of the same aggregate.

Another point of interest would be to note what results have been obtained in India by the use of rapid hardening cement and what special precautions, if any, are necessary in their use including [illegible] the period after completion necessary before traffic can be allowed on the road.

Mr. Turnbull mentions the use of long floats used longitudinally to finish the road surface, by which method any corrugations formed by [illegible] are [illegible]. This certainly seems correct [illegible] but [illegible] screeds and tampers which are worked transversely to the line of the road. The writer has found that by this method there is a tendency for depressions or long corrugations to be formed along the length of the road unless careful precautions are taken. One of the most frequent causes of trouble [illegible] which should be absolutely avoided. Another cause of trouble [illegible] is thoroughly well consolidated [illegible] high degree [illegible] in the crown of the road [illegible] being continually dragged [illegible] results. It would also be interesting to note what results, if any, [illegible] have been achieved in India with [illegible] concrete composed of a [illegible] top coat of [illegible] stone. Data regarding the use of [illegible] or other hardening applications would be of interest. In this connection also, in the event of [illegible] further [illegible] should be [illegible] removing the "laitance" from the surface prior to applying the hardening application.

With regard to expansion joints, the provision of such at 100 feet intervals seems to take care of any expansion between the long [illegible]. Mr. Turnbull mentions 20 feet traffic lanes as being advisable with longitudinal expansion joints between adjoining slabs. It is found that the general width for Grand Trunk roads

is 12 feet in which case no central longitudinal expansion joint would seem to be necessary, also in many cases the writer has noticed concrete roads of say 15 feet width with a central longitudinal expansion joint. This would seem to be unnecessary and Mr. Turnbull's comments would be welcome.

The Author's reply.—The questions raised by Mr. Gunnell are extremely interesting as they bring into prominence details which have of necessity been omitted in the paper.

1. *Gauge of aggregate best suited for different thickness of concrete pavements.*—It is generally agreed that the more coarse aggregate that can be incorporated into the concrete mixture the greater its strength and resistance to abrasion. The actual quantity is however limited by the workability required for finishing operations.

The following may be taken as sound practice for the maximum size of coarse aggregate in plain concrete slabs :

Single Course.—One-third the thickness of the concrete.

Two Course.—Top layer, half the thickness. Bottom layer, one-third the thickness.

It is the author's opinion that the greater the maximum size of coarse aggregate that can be used the better. It is regretted that at the moment no figures are available showing the density and strength of concrete made with different gradings of the same aggregates and cement of Indian manufacture.

2. Indian rapid hardening cements are in effect ordinary Portland Cements with a greater fineness of grinding. They acquire the same strength in three to four days as ordinary Portland Cements in 28 days.

The term "rapid hardening" must not be confused with "quick setting", as Indian rapid hardening cements are all slow setting.

A concrete road slab constructed with rapid hardening cement could be put into service after 3 days.

There are no special precautions to be observed in the use of rapid hardening cement other than the following —

(*a*) Store rapid hardening cement in a dry place and use as soon as possible. Owing to the extremely fine grinding it is subject to the action of any humidity in the atmosphere.

(*b*) Use it in exactly the same way as ordinary Portland Cement.

A point that is not always realized is that due to its fineness, it is rather lighter than ordinary cement and instead of the customary 90 pounds being assumed as the weight per cubic feet, rapid hardening cement may be taken as 80 pounds per cubic feet. That is to say, when measuring the quantities of materials, the ordinary 1 cwt. bag of standard cement which is assumed to contain 1·2 cubic feet, may be taken as 1·4 cubic feet, where rapid hardening cement is used

(*c*) Use as little water for mixing as is consistent with workability.

(*d*) Mix very thoroughly.

(*e*) Cure thoroughly for three days.

The author's opinion is that generally rapid hardening cement is not necessary for the construction of concrete road slabs. However for the last sections of the slab, it may be advantageous to use it, especially for a road that has to be put into service as quickly as possible. It is particularly useful in the repairs of trenches opened in concrete roads in busy throughfares.

3. *Longitudinal Floats.*—These are common practice in Hyderabad State but elsewhere in India there appears to be a disinclination to use them, and where they have been tried, the average cooly finds them exceedingly awkward owing to their length.

4. *Side Forms.*—The author is in full agreement with Mr. Gunnell as to the importance of having carefully placed rigid side forms. In his opinion a satisfactory road can only be built with carefully laid structural steel forms. Wooden forms warp after a certain amount of usage, and this is reflected in the finished surface of the road.

5. *Two Course Pavements.*—The Calcutta Improvement Trust has probably carried out the largest programme of two course construction. Their practice as in Central Avenue, is as follows :—

Top Course.—Thickness 2 inches. Coarse aggregate ¾ inch to ¼ inch. Proportions 1: 1: 2.

Bottom Course.—Thickness 5 inches. Coarse aggregate 1½ inches to ¼ inch. Proportions 1: 2: 4.

6. *Sodium Silicate.*—No data is available in India regarding the comparative rate of wear of concrete road slabs treated or untreated with sodium silicate. If good coarse aggregate is used, it is a moot point as to whether any surface application is necessary. The stone takes the wear.

Whilst hardening of the surface does occur, there is no proof that there is any beneficial result on the concrete as a whole and the practice is decreasing.

7. *Transverse Expansion Joints.*—Mr. Gunnell mentions 100 feet intervals. This would necessitate an expansion joint ¾ inch wide together with two intermediate contraction or dummy joints. Joints of this width *i.e.* ¾ inch are not advisable. It is better practice to have them at 35 feet intervals and make the width ⅜ inch.

Longitudinal Expansion Joints.—Except in very wide city streets longitudinal expansion joints are never used, and in the case of such streets the expansion joints are placed between the curb and the slab where they are out of the way of the traffic. The type of longitudinal joint between adjacent slabs is known as a construction joint and is usually of the plain butt type—sometimes with dowels or some other method of transferring the load. A construction joint is necessary up to a width of about 15 feet.

Mr. A. W. H. Dean.—Do you recommend the use of the bag of cement taken at 1.20 cubic feet in proportioning concrete mixtures or the cubic feet measured in a box?

The Author's Reply.—The bag of cement assumed to contain 1·2 cubic feet should always be taken as the unit of measurement. A cubic feet of cement can be so measured in a box that the weight may be as low as 60 pounds.

B. Replies to Question raised in the Discussion at the Congress.

(The author in reply to the discussion wishes to express his appreciation of the contributions thereto, as they indicate the keen interest which is now being taken in the problem of evolving an economical type of road).

I. In reply to Mr. Hyde's question as to hexagonal hoop reinforcement the author has had no practical experience of this and would not like to express an opinion until it has been investigated. Messrs. J. C. Gammon Ltd., have laid several bridge roadways recently and possibly a report could be forthcoming in time for next years Congress.

II. Mr. Modak's questions are replied to as follows :—

Concrete road slabs are designed for average traffic. It is the consensus of opinion that the fatigue behaviour under repetitions of flexural stress is the controlling factor. The lastest researches are in practical agreement on the following which are quoted from an American Authority.

"1. When the stress does not exceed 50 per cent. of the ultimate strength or when safety factor is not less than 2 the concrete will stand a practically unlimited number of stress repetitions without failure.

2. When the stress is lower than 50 per cent. of the ultimate strength or when the safety factor is greater than 2, the repetition of stress is actually beneficial and strengthens the concrete.

3. When the stress exceeds materially 50 to 55 per cent. of the ultimate strength of the safety factor is less than 2. continued repetition of stress will cause failure or breaking of the concrete.

4. When the safety factor ranges between 1 and 2 the number of repetitions required to cause failure varies with the number, decreasing as the safety factor decreases.

5. When there is a period of recovery between stress applications the fatigue action is minimized.

6. There is a difference in the fatigue behaviour of concrete under repetitions of compressive and flexural stress, the action under flexural stress being the less severe for the same percentage of the ultimate strength.

In a pavement subjected to flexural stress, the resulting compressive and tensile stress in the outer fibres of the slab are equal. The tensile strength of concrete is only a small fraction of its strength in compression. Consequently when the flexural stress reaches relatively high percentages of the ultimate modulus of rupture the resulting tensile stress is a high percentage of the ultimate tensile strength, while the compressive stress is a relatively small percentage of the ultimate compressive strength.

Therefore, when flexural stresses amounting to more than 50 per cent. of the ultimate modulus of rupture are repeated, the concrete becomes fatigued in tension, but the compressive stress remains below the fatigue limit in compression.

All pavement slabs should be designed to carry the predominating wheel loads with a safety factor of at least 2. By selecting a design fulfilling this requirement, an unlimited volume of such traffic may be carried without fatigue of the concrete. The stresses and resulting safety factor for the assumed design should then be determined for the infrequent heavier loads.

The wheel load characteristics of traffic which a specific highway will be called upon to carry after improvement may be easily determined. A study of the area in which the highway is located, the number of each size of truck registered in the area, the population density and the relation of the proposed improvement to other highways will aid the highway engineer to make conservative and rational traffic predictions. These predictions may be checked by using well established traffic study methods involving inexpensive short traffic counts on improved roads of similar characteristics."

Rubber is not advocated for expansion joint material in India as in all probability it would perish.

The curing period can be reduced to three to four days by using rapid hardening cement, therefore the very simple procedure of using this type of cement for the last ten days work would remove the inconvenience which Mr. Modak has experienced.

The author regrets he is unable to agree with Mr. Modak's statement that "concrete roads are not suitable for every or all kinds of traffic," especially so when he mentions heavy steel tyred traffic. Present day practice in India indicates that cement concrete is the final resort of all engineers of any experience who are faced with the problem of providing an economical road surface which will withstand the destructive effect of the bullock cart. This is very evident from the fact that in many provinces, cement concrete haunches are being provided for heavily trafficked roads to meet these conditions.

His remark anent economy is somewhat difficult to appreciate, as the prevailing practice in the arterial roads in Bombay Municipality is to lay sheet asphalt on 4 inches to 6 inches of cement concrete. The actual cost of this type is about 40 per cent. greater than a cement concrete road and the average maintenance charges on asphalt in Bombay are about twelve annas per square yard per annum, whereas on Argyle Road which is now four years old, it is doubtful if the maintenance has been one anna per square yard per annum.

Mr. Modak's statement that the addition of a wearing carpet of asphalt to a concrete slab increases the strength of the slab is somewhat surprising. Asphalt has practically no flexural strength.

III. *The following are the replies to Khan Bahadur Faruqui's questions* :—

The Khan Bahadur has evidently misread my remarks as I stated "an economical design of a concrete slab that will resist these forces." His interpolation of the word "aspect" somewhat alters the meaning.

It is a simple matter however to consider the economical aspect of various types of roads.

The basis of economical comparison can be taken as the average annual cost per annum to the taxpayer, and a simple logical formula is as follow :—

Where :—

$$C = \frac{I + i + M - S}{N}$$

C = The average annual cost per sq. yard per annum.
I = The initial cost per sq. yard.
i = The total interest paid on I say 5 per cent. during the life considered.
M = The total maintenance and repairs to date.
S = The salvage value at the age considered.
N = The age of the road in years.

A more accurate discussion of the economics of proposed road expenditures was published in the Indian Concrete Journal of December 1933.

As regards actual design of the slab this is discussed very fully in "The Design and Construction of Concrete Roads" by R. A. B. Smith.

In my reply to Mr. Modak I have explained the part that fatigue takes in the design of concrete road slabs.

As regards shrinkage and expansion of the concrete slab the statements in my paper have been definitely proved by many experiments carried out by reliable authorities.

A 4 inches slab is the minimum thickness that has been tried out in other countries, and in India the Khan Bahadur has probably had more experience than others in the 2 inches and 3 inches slabs constructed by him in the United Provinces.

The longitudinal cracking in the short length on the Moghal Serai-Benares Road is somewhat hard to account for, but may possibly be due to warping or non uniform foundation conditions as explained in my paper under "subgrade."

The advantages of having a longitudinal joint are:

(a) Ease of construction especially with hand finishing methods, as the 20 feet tamper for the full width is rather awkward for the average cooly to handle.

(b) It enables the road to be constructed in half widths—thus allowing the traffic to use the road.

(c) Owing to warping any road slab over 15′ in width is subject to longitudinal cracking.

The question of longitudinal joints will be discussed in the author's reply to Mr. Dean.

Khan Bahadur Faruqui in commenting on joints is confusing two entirely different methods of laying concrete roads. In the United Provinces and Hyderabad the roads were laid in alternate bays, where expansion joints are not necessary.

His statement that water cement ratio should be kept at a minimum is exceedingly sound, the basic idea of this however is that excess water weakens the strength of the concrete and is conducive to segregation, the heavier coarse aggregates sinking to the bottom of the slab.

IV. *Mr. Burt's* questions regarding the use of rapid hardening cement and silicate of soda have been discussed in the author's replies to other delegates.

V. *Mr. Macfarlane's quesiton.*—Precast slabs have frequently been tried, but owing to the numerous joints they have never been a success. The author does not recommend their use, except in very exceptional cases.

VI. *Mr. Daniel's* interest in this paper is exceedingly gratifying to the author, as Mr. Daniel's experience in the Chingleput experimental road near Madras enables him to speak with probably much more authority than anyone else in India.

The question of design has already been discussed in my reply to Mr. Modak.

Regarding the diagram mentioned by Mr. Daniel, it would appear that he has substituted the actual modulus of rupture in the formula whereas S = the allowable working stress and equals half the modulus of rupture.

VII. With regard to *Mr. Taylor's* experience with the appearance of sodium silicate chrystals on the underside of the bridge roadway—the author regrets he is unable to express an opinion without having investigated the phenomena personally. In all probability Mr. Taylor's assumptions as to the cause are correct.

In reply to his question on the use of sodium silicate as a curing agent the following extract from the Journal of the American Concrete Institute is of interest with reference to the results of a series of experiments on different methods of Curing Concrete.

"From these results it would appear that the coating of Sodium Silicate was of little or no value as a means of curing concrete

The lowest strengths at 3 months and one year were obtained with concrete containing the 2 per cent. calcium chloride admixture cured in air the sodium silicate and air cured cylinders which were from 45 to 55 per cent. of that for water curing and about 60 per cent of that for 13 days moist curing at these two ages."

VIII. *In reply to Mr. Dean's questions.*—Experience indicates that the types of longitudinal joints shown at the end of the author's paper [after page 228] are quite effective.

The dowelled joint with premoulded expansion joint material is possibly the best type in use at present. It is exceedingly important to prevent the access of water through the joints to the subgrade as it tends to reduce the support to the slab and there is no evidence that any joint filler so far used has been effective under all conditions.

Most premoulded joint fillers at present in use have a bitumen matrix with or without admixtures such as wood fibre etc., and are used in sheets.

One of the latest experiments consists of a strip of annealed copper about 6 inches wide laid horizontally through the joint and provided with a small central corrugation to take up horizontal slab movement. This type prevents the ingress of water to the subgrade, but its life is unknown.

The question of the amount of mixing water required depends on several factors but it generally between 5 to 6 gallons per bag of cement which should include all free water carried by the aggregates.

The water cement ratio law is one of the most important discoveries of modern concrete research, and may almost be termed a basic law. It has been proved that for any particular aggregates and methods of mixing, placing and curing, the strength of the resultant concrete depends solely on the water-cement ratio law, whereas economy depends upon the amount of aggregate which can be added whilst maintaining the consistency that renders the concrete workable.

It is desirable to use a slightly oversanded mix in order to facilitate finishing operations especially with hand finishing methods.

The initial set of rapid hardening cement is the same as for ordinary portland cement.

IX. The reply to *Mr. G. Reid Shaw's* request for information on the subject of concrete, is as follows :—

'Light-weight concrete is made either by a chemical process or mechanically. The chemical method is based upon a reaction between an alkaline metal and water when mixed with cement and other ingredients. The water is decomposed into its elements, the oxygen makes an alliance with the metal, and the free hydrogen creates little bubbles in the mixture, which swells up to several times its original volume and then gradually hardens in the same way as ordinary concrete. It is possible in this manner to produce a concrete so light that a cubic foot thereof weights only 20 pounds At about 42 pounds per cubic feet, the ultimate compressive strength averages 400 to 500 pounds per square inch.

'The texture of the material resembles cork. It has small and evenly distributed cavities, which make up 70 per cent. of its volume. Each one of these cavities is a closed compartment surrounded by thin walls, and this is the reason the material has such good insulating qualities. The material can be made in blocks or it can be cast *in situ*.

Another advantage of expanded concrete is that it can easily be worked with common wood-working tools. It can be sawn and grooves can be made in it for electric and other conduits.

'Lightweight concretes are also made with breeze, clinker, or pumice as aggregates. To obtain a lightweight pumice concrete for use as filling, sand must not be added. The densities of 4 to 1 pumice concrete with and without sand have been found to be about 98 and 85 pounds per cubic feet respectively.

X. *Mr. K. G. Mitchell* raised a very interesting point regarding what would happen if the concrete slab wore out.

The customary procedure is to resurface with about 3 to 4 inches of new concrete, sometimes lightly reinforced with steel fabric. The use of cotton fabric to form a cleavage plane as mentioned in my introduction would probably facilitate any repairs.

As regards the failures and successes of cement macadam, the one quoted in Mr. Greening's paper has failed but this type of construction has been quite successful at Nagpur, Vellore, and elsewhere. It does however require very careful supervision and the author prefers the all-concrete slab.

Mr. H. M. Surati (on behalf of the Author of Paper No. 9): Mr. Chairman and gentlemen, there was some criticism about longitudinal joints and Mr. Dean has to some extent replied to that. We adopted longitudinal joints because we could not close the whole road and had to leave half open for traffic. And as a result of having a longitudinal joint we avoided heavy tamping on longer widths with a camber of 2 inches. It is very difficult to keep the shape of the camber and to maintain an even surface over the whole width of the construction, but with this centre joint we had only about ¼ inch curvature and the surface was uniformly finished.

Mr. Daniel wanted to know about the rapidity of our construction at Hyderabad. We actually found that the asphalt road took longer to construct than the cement concrete road. [*Vide* page 234, para. 16 (1) of Paper No. 9.] In regard to lime-concrete, it was only an experiment and the idea was to reduce the cost, and when we find it is wearing we shall just give it an asphalt coating. Of course we found it wearing, but not so badly as the asphalt surface, the lime concrete serving as foundations. Somebody asked about the mixing. The mixing was done by machine. We found hand mixing was not so uniform in quality, at times being very dry or not properly mixed. Mr. Dean wanted to know about cuts. We are cutting our cement roads; for all services we cut our roads with chisel and hammer and again repair it in the usual way. In the case of an asphalt road we found that it was difficult to keep the cut to the same shape, but cement concrete cutting remains to the same shape. That is all I have to say.

Chairman: Now, gentlemen, I would ask you all kindly to accord a most hearty vote of thanks to the authors of these three most interesting and instructive papers, and also to all gentlemen who have taken part in the interesting discussion. After which I shall ask Mr. Hyde kindly to take this Chair.

A vote of thanks was passed with acclamation.

Mr. H. A. Hyde M.C., Chief Engineer, P. W. D., Central Provinces, then took the Chair.

Chairman: Gentlemen, before we break off this morning I want to take the opportunity of proposing a very hearty vote of thanks to Mr. K. G. Mitchell for the very great trouble he has taken and the great amount of work that he must have undertaken in getting up and running this Congress. (Applause.) I did not take part in the tour myself but I understand from those I have spoken to about it that it went like clockwork from start to finish, (Applause) and that every possible arrangement was made, not only to show you interesting work but for the convenience and personal comfort of all taking part in the tour. There is no difficulty whatever in realizing the very great amount of work necessary to run a congress like this, and I want to just repeat that we all appreciate it very much indeed and to ask you for a hearty vote of thanks to Mr. Mitchell. (Applause.)

A vote of thanks to Mr. K. G. Mitchell was carried with acclamation.

Mr. K. G. Mitchell: Mr. Chairman and gentlemen, I thank you very much. It has been a certain amount of trouble but it has also been a very great pleasure, and if it results in some permanent organization for the future, then what little trouble there has been will have been well worth while. I may say I do not think Mr. Hyde is quite fair. This is the second time he has sprung this on me in two days. (Laughter.)

Chairman: We meet again at half past two.

The Conference adjourned till 2-30 P.M.

The Congress re-assembled after Lunch at 2-30 P.M. with the Honourable Mr. D. G. Mitchell, Secretary to the Government of India in the Department of Industries and Labour, in the Chair.

The following Report of the committee appointed on the first day was taken into consideration:—

Report of the Provisional Committee of the Indian Roads Congress.

The first meeting of the Indian Roads Congress appointed the following committee to report upon the necessity for an organisation of a permanent Indian Roads Congress.

Provinces.

Mr. A. Vipan.	Madras.
Mr. L. E. Greening.	Bombay.
Mr. D. J. Blomfield.	Bengal.
Mr. C. F. Hunter.	United Provinces.
Mr. S. G. Stubbs, O.B.E.	Punjab.
Mr. O. H. Teulon.	Burma.
Mr. N. G. Dunbar.	Bihar and Orissa
Mr. H. A. Hyde, M.C.	Central Provinces.
Mr. B. F. Taylor, V.D.	Assam.
Mr. G. A. M. Brown, O.B.E.	North-West Frontier Province.
Mr. A. Brebner, C.I.E.	Central Public Works Department.

Indian States.*

Rai Bahadur A. P. Varma.	Patiala.
Diwan Bahadur N. N. Ayyangar.	Mysore.
Mr. P. L. Bowers, C.I.E., M.C.	Jaipur.

Business.

Mr. H. E. Ormerod.

Col. G. E. Sopwith.

Mr. G. G. C. Adami.†

Military Engineering Services.

Major W. B. Whishaw, M.C., R.E., Engineer in Chief's Branch.

2. The Committee met at 6 P.M. on Monday, the 10th December, Mr. Hyde being in the Chair, and now reports as follows.

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*Two additional representatives of Indian States, *viz.*, Rai Bahadur S. N. Bhaduri (Gwalior) and Mr. M. A. Zeman (Hyderabad) were subsequently elected *vide* page 268.

†Mr. C. D. N. Meares has since been appointed in his place.

Necessity for some permanent body.—It is highly desirable to constitute a permanent body which may be called the Indian Roads Congress. The objects of such a body should be:—

To provide for a regular pooling of experience and exchange of ideas on all matters affecting the construction and maintenance of roads in India; to recommend standard specifications; and to provide for the expression of the opinion of the Road Engineering profession on matters affecting their work. The functions of such a body should be strictly confined to professional and technical matters.

Qualifications for membership.—Subject to the specific or general approval of the General Committee, membership should be open to all professionally qualified Engineers engaged or concerned in the construction and maintenance of roads whether in public or private employ. The standard of professional qualification should be not less than that required for direct recruitment to the rank of assistant Engineer in a Provincial Service. The General Committee might also admit persons holding the rank of Assistant Engineer in a Provincial Service or equivalent rank though not qualified by examination. In addition the professional members, non-professional gentlemen closely concerned or interested in roads should be admitted as associates.

Subscriptions.—There should be only two classes of constituents, namely, members and associates. The subscription should be Rs. 10 per annum for members and Rs. 50 per annum for associates.

6. **Privileges of constituents.**— All members and associates should be on an equal footing as regards attending and speaking at meetings, subject to the necessary arrangements regarding travelling allowance. All constituents would receive copies of the printed proceedings of annual Congresses and such other literature as may be circulated. It must be recognised that for the majority the benefits will be confined to the receipt of the proceedings and other literature, although it is to be hoped that a large number of those in the Province in which the annual Congress is held will be able to attend Any member or associate should be at liberty to submit a paper for discussion. The acceptance of Papers will vest in the General Committee, but the General Committee might find it necessary to delegate this matter to provincial or State committees.

7. **Attendance at meetings.**—The attendance of public servants at annual meetings of the Congress will depend upon the arrangements for finance. In any event they will be nominated by the local Government or by the provincial committee. Non-official constituents will attend at their own expense or at the expense of their principals.

8. **Management.**—The management of the Congress should be in the hands of a General Committee and Provincial or State Committees. The funds and property of the Congress should vest in the General Committee.

(a) *General Committee.*—The General Committee should be constituted as follows:

(i) The Chief Engineer in charge of roads of each Governor's Province or his nominee.

(ii) The Chief Engineer of the Central Public Works Department.

(iii) The Consulting Engineer to the Government of India (Roads).

(iv) Five representatives of States to be elected by the representatives of States present at each annual meeting.

(v) Three representatives of non-official members and associates elected by the non-official members and associates present at each annual meeting.

(vi) One representative of the Military Engineering Services.

The Consulting Engineer to the Government of India (Roads) would be *ex-officio* Secretary of the General Committee.

(*b*) *Provincial or State Committees.*—Provincial or State Committees should be constituted by the Chief Engineer in charge of roads in each Governor's Province and certain States and should consist of officials and non-officials. The precise strength of the Committee and the representation of the official and non-official constituents to be determined by local considerations. The Chief Engineer in charge of roads in each Governor's Province and in each State in which a State Committee is constituted should nominate a Secretary from among the members of the Committee.

9. **Finance.**—It is difficult to estimate to what extent subscriptions will cover the cost of printing, postage and clerical assistance. Membership may take time to grow and the Government of India should be asked for a lump sum grant from the reserve in the Road Account to cover any deficit there may be during the first year or two. The largest item of expenditure will, however, be in connection with the travelling and halting allowances of delegates attending the Congress and in respect of the hire of transport for tours of inspection. The Committee fully recognise the force of the argument that the benefits of the Congress will accrue almost entirely to Provinces and States in improved and more economical roads. They also recognise the difficulty with which the Government of India will be faced in continuing to bear the whole cost of the Congress which is uncovered by subscriptions, if local Governments and States are unable to endorse the value of the Congress by bearing the expenses of sending their delegates to meetings. They feel, however, that the reserve in the Road Account constitutes a special fund —a fund which local Governments have not got—specifically intended to stimulate research and intelligence. They consider that those objects would be admirably served by such a Congress and that the saving of a duplicate experiment which the Congress should effect would alone be a justification for this expenditure from the reserve. They understand that the cost of the present Congress, including the tour, will amount to about Rs. 25,000 and they observe that this is equivalent to a grant for the construction of half a mile of experimental concrete road. In the present state of financial stringency, they do not think it reasonable to ask Provinces and States to defray the cost of their delegates. As already stated, Provinces and States have no funds specifically earmarked for such purposes and for the present at least many of them might be impelled to decline to meet this expenditure,

not because they doubt its efficacy, but because as a matter of general principle they have still to abstain from any additional expenditure however small and however beneficial until their budgets are balanced. It may be suggested that the expense involved could be met from existing budget provisions for travelling allowances of road departments, but the Committee feel that that budget provision has already been reduced to a level at which adequate inspection is difficult and that to draw upon that inadequate provision for relatively expensive journeys outside the province or State to attend annual meetings of the Congress would be a disservice to the objects of the Congress. They therefore recommend that for the next two years the Government of India should, in consultation with local Governments and States, continue to defray the cost of these meetings and they suggest that the approval of local Governments to such a course would be sufficient justification seeing that money not expended in this way would ultimately go to road authorities in some form or other. Failing this they recommend that the Government of India should permit local Governments to defray the cost of sending delegates to the Congress from their shares in the Road Account.

10. **Place of annual meetings.**—The Congress should meet in a different Province or State each year by invitation from the local Government or State concerned.

11. **First General Committee.**—The constituent Committee appointed to report should, if the Congress is constituted, continue to hold office until the next annual general meeting.

12. **Constitution and bye-laws.**—If the Congress takes permanent shape, it will be necessary to have a written constitution and bye-laws. These cannot be drawn up until the main lines of the future constitution and finance have been accepted by the Government of India in consultation with local Governments. Moreover, it is not possible for the constituent Committee in the short time at present available to attempt to draft these. It will therefore be necessary for the Committee to meet at some future date for this purpose. It is observed that the General Committee will not normally meet, save at the time of the annual Congress, but that on this occasion this will involve certain non-recurring expenditure which will presumably have to be defrayed from the reserve in the Road Account.

13. **Sub-Committee.**—The General Committee has accordingly appointed certain Sub-Committees, to undertake certain necessary work during the current year and to report to the General Committee, as follows:—

(a) *Drafting Committee*—

Mr. A. Brebner.

Mr. C. F. Hunter.

Rai Bahadur A. P. Varma.

Mr. K. G. Mitchell.

This Sub-Committee will deal with the draft constitution and bye-laws and will also act as a reading committee to accept papers for the next Congress.

(b) *Technical Sub-Committee—*

† *Mr. G. G. C. Adami.*

Mr. S. G. Stubbs.

Major W. B. Whishaw.

Mr. K. G. Mitchell.

This Sub-Committee will be instructed to deal first with the question of standardisation of units of weight and measure and of nomenclature. It will consider what technical questions are most urgent and suggest subjects for Papers at the next Congress. It will also act as an advisory research committee to recommend lines of further research and experiment.

14. **Venue of next Congress.**—The Committee consider that the Governments of Madras and Mysore should be approached with the suggestion that the next Congress should be held at Bangalore and should include tours of inspection from that centre of roads both in Mysore and Madras. Failing Bangalore, the Committee consider that the next Congress should be held either at Madras or at Calcutta subject to the approval of the local Government concerned.*

DISCUSSION.

Chairman: Gentlemen, I understand that you have all been given copies of the very useful report submitted by the Constitution Committee. Unfortunately, through sheer lack of time, they have not been able to complete the whole duty placed upon them, but they have given us a very clear lead and I think we should be able to come to some final decisions this afternoon. I propose to begin with asking if anybody has any remarks to make on the general aspects of the proposal, the general desirability of this Indian Roads Congress. Thereafter I propose to go through the paragraphs of the report one by one and call for remarks on each. Would anybody like to say anything on the general proposal for having a permanent Indian Roads Congress.

Mr. D. J. Blomfield: With regard to item 3 of the report of the Committee, the necessity for a permanent body, I think we all agree that this first meeting of the Indian Roads Congress has convinced us of the necessity for a permanent body; for, not only will it be of great value to us individually as engineers, but also of great value to the Provincial Governments which many of us represent. It will save Government a very great deal of duplication of experimental work on roads as well as keep them informed of the failures and the successes of the various treatments of roads. I have always thought it was a great pity that we are

*An invitation to hold the next Session of the Congress at Bangalore has since been received from the Government of H. H. the Maharaja of Mysore and has been accepted by the organizing Secretary on behalf of the Congress.

†Mr. C. D. N. Meares of the standard Vacuum Oil Company will serve on the Technical Sub-Committee *vice* Mr. G. G. C. Adami.

unable to see and hear more of what other provinces are doing in road work, and the creation of this body will certainly enable us to remedy this defect.

There is one point which I would like to bring up which I do not think has been considered in the Committee, that is that if one or more members of each Provincial Government receive the proceedings and papers of the Congress will they be entitled to have these reprinted for distribution amongst other engineers in the P. W. D.? If so, there will be no object in those other officers joining as members themselves, except possibly when the Congress is held in their province. I think this is an important point which we did not take up in the Committee.

Mr. B. F. Taylor: I should like to say, Sir, at once, on behalf of the delegates from Assam that we are firmly convinced that a Congress of this nature cannot but be of the greatest benefit to the profession in India and in particular to Assam. We are extremely grateful, and should like to place on record now our appreciation of the manner in which the Government of India have launched this Congress (Applause), and for the very generous financial assistance they have given to it. Assam, where we come from, the Government of India have been good enough to label as a 'backward tract,' or any how large parts of it. Well, I think it is a bit hard to be told you suffer from malnutrition by the fellow who is picking your pocket and preventing you from being anything else. I refer of course to the fact that the Government of India take the whole of the excise duty on kerosine and petrol produced in Assam. But, whether or not we are a 'backward tract', I can assure you that we engineers who have "to make bricks without straw" definitely feel that we are members of the "depressed classes". As our resources are very limited, it cannot but be of great good to us to visit other provinces and to hear from engineers of other provinces what they are doing with their larger resources and the better opportunities they have for trial and experiment, and a Congress such as this cannot but be of great benefit. It is all very well to read papers, if one has the time to read, which I fancy most of us have not, and it is still more difficult to write them, but to my mind the value of assembling like this lies not in the reading but in the discussion which follows, and still more in meeting the people who have written the papers or criticised them personally, and also in seeing the actual results which the papers describe. I therefore think, and I do not suppose anybody here holds any other opinion, that this must be of inestimable value, and I think it is up to us, apart from passing resolutions and adopting the Committee's Report, to say what we think most emphatically and definitely. I therefore beg to support the proposal for an annual Congress with all the emphasis I can command. (Applause.)

Mr. O. H. Teulon: Mr. Chairman and gentlemen: The Government of Burma has committed itself to support the proposal to constitute the Road Congress in that it has permitted two delegates to attend the recent tour and the Congress. The attitude of the local Government is necessarily coloured by the approach of separation and this involves a certain amount of detachment of outlook towards India's problems and organisations. As a result of attending this first Congress, I am more convinced than ever of the advantages to be gained by establishing the Congress upon a permanent footing. I take the view that the opportunity which the Congress affords of the interchange of ideas and the facilities it gives

for coming into personal contact with engineers and business representatives is of great value to the local Government. Upon my return to Burma I propose to recommend to the local Government that it gives it wholehearted support to the permanent constitution of the Congress. (Applause.)

The Hon'ble Mr. E. Miller: Mr. Chairman and gentlemen: On behalf of the Indian Roads and Transport Development Association I should like to give our hearty support to the proposal before us. In fact we consider that it is a definite step forward in the progress we are aiming at, namely, road development and co-ordination. (Applause.)

Mr. A. Vipan: Mr. Chairman and gentlemen: My own personal opinion is that an organisation such as the one now contemplated is essential. We, in Madras, feel that in regard to the problems of modern road construction having regard to the present day requirements, we are groping to a certain extent in the dark. For that reason and with a view to economise, the Indian Roads Congress, when permanently constituted, will fill a real need. (Applause.)

Rai Bahadur A. P. Varma: Mr. Chairman and gentlemen: I should like to associate myself with the remarks of the previous speakers on behalf of the various States. They have all asked me to express this opinion and they all whole-heartedly support the idea of the permanence of this Congress. (Applause.)

Chairman: Gentlemen: From the favourable tone of the speeches that we have heard and the representative character of the speakers, I think we may take it that the permanence of this body is a proposal to which we all agree. (Applause.)

Chairman: The discussion so far has covered the first part of para. 3, the previous two paragraphs require no discussion. Perhaps some members would like to say something regarding the objects of the Indian Roads Congress as defined in para. 3 of the report.

(No comments.)

Paragraph 4.—No comments.

Paragraph 5.—No comments.

Mr. A. W. H. Dean: May I ask if the Committee considered the possibility of having a third class of subscribers, namely, a corporate association of business firms. The International Roads Congress caters for that.

Mr. K. G. Mitchell: I think this subject was not very much discussed as far as I remember. Mr. Hyde was in the Chair. I think this matter was in our minds but we considered that membership should be individual and not corporate. It is very difficult to define the status of a corporation and how many people from it can get in.

Mr. H. A. Hyde: The idea was that the membership should be on an individual basis.

Chairman: Perhaps the sub-committee might further consider this point as opinion has been expressed in favour of corporate membership.

Paragraph 6.

Major W. B. Whishaw: I suggest that the last few lines are unnecessary and may be deleted, namely: "but the General Committee might find it necessary to delegate this matter to provincial or State committees."

Chairman: Is it agreed that the closing words in the 6th paragraph be deleted?

Mr. A. W. H. Dean: Does the question of "copyright" arise under the heading 'privileges of constituents'? I mean to say that nobody should be allowed to further publish the papers.

Mr. K. G. Mitchell: I think the Drafting Committee will have to consider all these details. What I think we had in mind was—and this will also meet to some extent the question raised by Major Whishaw—that the proceedings would be on sale. But naturally the price of the annual proceedings would be substantially more than the annual subscription. If they were on sale, presumably they would be under copyright subject to the general permission of the Committee to reproduce them for any special purposes. But that is rather a detail which will have to be gone into.

Chairman: Paragraph 7.—No comments.

Paragraph 8.

Major W. B. Whishaw: I suggest that under paragraph 8 (*b*) we should add Baluchistan.

Chairman: That is a point which the sub-committee will take note of and deal with.

Mr. A. S. de Mello: I suggest that the number of representatives under sub-para. (*a*) (*v*) be increased to 5, so that opportunity might be given to those who use the roads to be represented on the Committee.

Chairman: That is another point which I think the sub-committee might take into consideration.

Mr. P. L. Bowers: Regarding sub-para. (iv) of para. 8, I would suggest that such States as have got a large mileage of roads should come on it without being voted for. For instance, if we make the limit between 2,000 and 3,000 miles or more, such States should be treated as a province and their Chief Engineer should come on to it without being voted for by the other States..

Chairman: That is another point on which the sub-committee will have a certain amount of deliberation.

Paragraph 9.

Chairman: The Committee has said all that could be said about para. 9. I cannot talk on behalf of the Government of India but can only give you my own views. I think this proposal will be favourably considered, but you must always remember that the man who pays the piper calls the tune. I hope myself the Government of India will not be too particular in their specifications but I think they are quite likely to have something to say about the length of the tune. In other words, it is extremely unlikely that we will give any indefinite pledge to pay the expenses of anybody who chooses to come. There must obviously

be a limit, but in other respects I think I may say on my own behalf that the proposal will be given very favourable consideration. (Applause.)

Paragraph 10.—No comments.

Paragraph 11.

Mr. A. S. de Mello: I suggest that the first general committee should have power to co-opt members.

Chairman: A point arises from the constitution of the first provisional committee which has three members for the States. I understand that for the final Committee it is proposed to have five members from States. Perhaps the meeting would agree now that for this committee which will hold office for the next year the representatives of States should also be five. Is there any objection to the proposal?

(No objection was raised.)

Then we may take it that for the next year—the committee will consist of 5 representatives of Indian States. I leave it to the delegates from the States to appoint the two extra members, which I presume they will do in the course of the afternoon and intimate them to the Secretary.*

Mr. D. Macfarlane: I should like to make an inquiry just out of curiosity. I have no fixed ideas myself on the subject. I want to know whether the technical committee who are going to decide on the papers that are going to be received have formed any idea themselves yet as to the limit and scope of papers. This is an Indian *Roads* Congress but at the same time in our tours we were shown, and we were very glad to see it too, certain cases of *bridge* construction. Are we going to allow papers on bridge construction, arboriculture and various other sub-heads which are connected with roads. I have no ideas myself on the subject.

Mr. H. A. Hyde: Bridges would certainly be included.

Mr. K. G. Mitchell: I do not think the technical committee would necessarily limit the papers. I think our idea was to suggest the most urgent matters on which papers would be received. That would not preclude any body from writing any paper which concerns roads, which he thought would be of interest, including bridges. All that the technical committee did was to suggest certain subjects on which it was very necessary that we should have papers.

Chairman: This matter may be safely left to the discretion of the committee itself.

No remarks on other paragraphs.

Chairman: That concludes the deliberations of this afternoon. On your behalf, I would like to thank the members of the committee for the very useful work they have put in in connection with this report. I hope the labours of the sub-committee will be successful and that they will come to satisfactory conclusions.

Mr. C. D. N. Meares then invited such of the delegates as were interested in the subject to inspect the soil stabilization work that was being carried on at the junction of Badli Road and Karnal Road.

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*Rai Bahadur S. N. Bhaduri (Gwalior) and Mr. M. A. Zeman were elected as the two additional representatives of States.

Chairman: That concludes the deliberations of this Congress. I hope you have enjoyed your tour and the Congress since I think some members expressed a vote of thanks to the Government of India for putting up the money. I think I shall be able to assure the Government of India that the money appears to be extremely well spent.

A vote of thanks was proposed to the Chairman and then the Congress dispersed.

APPENDIX A.

INDIAN ROADS CONGRESS TOUR.

The following left Delhi at 11-35 on the night of Tuesday, the 4th December, by a specially chartered train.

Mr. A. Vipan, Special Engineer for Road Development, Madras.

Mr. D. Daniel, District Board Engineer, Tinnevelly.

Mr. L. E. Greening, Deputy Secretary, P. W. D., Bombay.

Mr. N. V. Modak, City Engineer, Bombay Corporation.

Mr. D. J. Blomfield, Chief Engineer, P. W. D., Bengal.

Mr. V. A. Stein, Superintending Engineer, Calcutta.

Mr. Pramatha Nath De, District Board Engineer, Burdwan.

Mr. S. S. Bhagat, Executive Engineer, Meerut.

Mr. A. Eastmond, M.C., Executive Engineer, Agra.

Mr. S. G. Stubbs, O.B.E., Superintending Engineer, Ambala.

Mr. S. Bashiram, Executive Engineer, Ambala.

Mr. O. H. Toulon, Chief Engineer, P. W. D., Rangoon.

Mr. H. Hughes, Superintending Engineer, Rangoon.

Mr. J. G. Powell, Chief Engineer, P. W. D., Bihar and Orissa.

Mr. N. G. Dunbar, Deputy Chief Engineer, Patna.

Captain G. F. Hall, M.C., Superintending Engineer, Muzaffarpur.

Mr. P. V. Chance, Superintending Engineer, Raipur.

Mr. B. F. Taylor, V.D., Offg. Chief Engineer, P. W. D., Assam.

Mr. G. Reid Shaw, Superintending Engineer, Shillong.

Mr. K. E. L. Pennell, Assistant Chief Engineer, Shillong.

Mr. S. N. Chakravarty, Municipal Engineer, Delhi.

Mr. A. Croad, Superintending Engineer, Central P. W. D., Delhi.

Mr. A. W. H. Dean, M.C., Executive Engineer, Central P. W. D.

Mr. M. A. Abbassi, Assistant Engineer, Central P. W. D., Delhi.

Lt.-Col. E. L. Farley, M.C., R.E., O.B.E., Lucknow.

Mr. H. M. Surati, Divisional Engineer, Roads, Hyderabad (Deccan).

Diwan Bahadur N. N. Ayyangar, Chief Engineer and Secretary to Government, P. W., Railway and Electrical Departments, Mysore.

Rai Bahadur S. N. Bhaduri, Chief Engineer, P. W. D., Gwalior.

Mr. G. B. E. Truscott, Chief Engineer, Travancore.

Rai Bahadur A. P. Varma, Chief Engineer, Patiala.

Mr. S. G. Edgar, Superintending Engineer, P. W. D., Jodhpur.

Mr. D. G. Sowani, Executive Engineer, Kolhapur.

Mr. D. V. W. Ottley, Chief Engineer, Patna (Orissa State).

Mr. G. G. C. Adami, Burma Shell Company, Calcutta.

Mr. H. E. Ormerod, Vice-President, The Indian Roads and Transport Development Association.

Lt.-Col. H. C. Smith, O.B.E., M.C., M.L.C., General Secretary, The Indian Roads and Transport Development Association.

Mr. W. J. Turnbull, the Concrete Association Bombay.

Mr. T. C. Marschalko, Texas Company, Bombay.

Mr. W. H. Kerr, Shaw Wallace and Co., Bombay.

Mr. Nurmahomed M. Chinoy, The Bombay Garage, Bombay.

Mr. W. H. Rowlands, Burmah Shell Company, New Delhi.

Mr. R. W. Parkhurst, A.M.I.E., Aust., (Trinidad Lake Asphalt Operating Co., Ltd., Sydney, N. S. W.).

Mr. K. G. Mitchell, C.I.E., Consulting Engineer to the Govt. of India (Roads).

2. Mr. G. W. D. Breadon, District Board Engineer, Gurdaspur, Capt. W. B. Robertson, R.E., Garrison Engineer (Civil), Quetta, Major W. B. Whishaw, M.C., R.E., Army Headquarters, Simla, Mr. D. Macfarlane, Chief Engineer and Secretary to Government, Punjab, Mr. G. H. Hunt, M.C., Under Secretary to Government, Punjab, and Mr. W. Brodie, Burmah-Shell Company, Karachi, joined the party at Amritsar and Lahore.

3. On arrival at Amritsar the party was met by Mr. Macfarlane, Rai Bahadur Lala Sant Ram, Superintending Engineer, Mr. L. A. Freak, Executive Engineer, and Lala Behari Lal, Assistant Engineer, and after a short visit to the Golden Temple left for Lahore inspecting the Grand Trunk Road from Amritsar to Lahore, Mayo Road, the Mall at Lahore, and a short portion of the Multan Road, particulars of which were furnished by the Punjab Government as follows:

Wednesday morning, December the 5th.

I. Grand Trunk Road—Amritsar to Lahore.—This section of the Grand Trunk Road connects the two largest cities in the Punjab. It is, therefore, of particular interest to Engineers as it is subjected to very heavy and fast moving traffic, the intensity of which gradually increases towards Lahore where it reaches a figure of 560 tons per yard width per day.

With the exception of the portions in the vicinity of Amritsar and Lahore the width of this section was originally the same as that of the remainder of the Grand Trunk Road, *i.e.*, 12 feet. It has recently been increased to 20′ and is the only continuous stretch of road of this width in the Province. This increase is a very great improvement both in convenience and safety to traffic, especially during wet weather, as vehicles can now pass or overtake one another without having to go on to the berms.

The road throughout consists of water bound limestone macadam, surfaced with Shalimar Tar, the specification for the latter being as follows per 100 sft. of surface:—

1st coat . . .	Shalimar Tar No. 2	28 lbs.
	Grit ($\frac{3}{8}''$—$\frac{3}{4}''$)	3 c.ft.
2nd and subsequent coats.	Shalimar Tar No. 2	14 lbs.
	Grit ($\frac{1}{8}''$—$\frac{3}{8}''$)	1½—2 c.ft.

Many of the miles have not been reconsolidated since 1927, while tar surfacing is renewed on an average once every 18 months.

Within about 9 miles from Lahore (where arrangements have been made by the Dunlop Rubber Company for a demonstration of a pneumatic-tyred bullock cart) it will be noticed that owing to the existence of brickfields there is a large increase in traffic of heavily laden bullock-carts. These with their iron-tyred wheels cause heavy wear, more especially on the left hand side of the road. Owing to this and the other heavy traffic, funds recently been allotted for increasing the width of the road from 20′ to 30′ between the Shalimar Gardens (mile 306), and the Railway underbridge (mile 309½) and the work is about to commence.

The short length of the heavily trafficked one way passages through the Railway underbridge has recently been reconstructed with reinforced cement concrete (1:2:3½) of 7″-5″-5″-7″ section and tar surfacing which appears to be standing up very well.

II. Mayo Road.—This road which is the main route between the Railway Station and Lahore Cantonments is subjected to very heavy traffic of all descriptions with the exception of brick-laden bullock-carts. The absence of this latter type of traffic as compared with the Grand Trunk Road is evidenced by the increased life of the road which has not been reconsolidated since 1925 but is resurfaced with tar on an average once a year, the specification being the same as quoted above.

III. The Mall.—This is the most fashionable and heavily trafficked thoroughfare of Lahore. No bullock-carts of any description are allowed to use it with the result that it has not been found necessary to reconsolidate it since its first reconstruction as long ago as 1916. It is resurfaced with tar on an average every second year.

IV. Multan Road.—This is another instance of a road which is subjected to heavy wear through incoming brick-laden bullock-cart traffic. Work is about to start (with a 50 per cent. grant-in-aid from the Reserve of the Central Road Fund) on a 7′ wide concrete track on the west side of the road to which, it is hoped, the incoming cart traffic will be entirely confined. The work is in the nature of an

experiment, and should it prove successful a similar track will probably be provided on the east side at a later date. It would have been preferable to adopt the same procedure with regard to the widening of the Grand Trunk Road referred to above, but the cost is prohibitive at present being approximately four times that of a surfaced water bound macadam road.

4. The whole party was then entertained to lunch by the Hon'ble. Sir Jogendra Singh, Minister of Agriculture who, after lunch, welcomed them in the following speech :—

Gentlemen, It gives me great pleasure to welcome you all here today and to be the first person to wish the Indian Roads Congress all success on the occasion of its first gathering. I feel that the inauguration of this Congress which has brought together eminent engineers and public men, marks an epoch in the history of road development in India. I know, we owe it to the energy and enthusiasm of Mr. Mitchell that this Congress has met. He and I have worked together in the Punjab and I know how anxious he has always been to weave a web of communications. I remember asking him to make a start by inducing the District Boards to begin with 10 miles of *kucha* motorable demonstration roads. It was not long before we had graders working almost in all the districts. The Buildings and Roads Branch now maintains good *kucha* service roads, where cars can travel at least at the rate of 40 miles an hour.

I cannot help feeling really proud that your organising Secretary has relied on the principle that "first impressions are always the best" by selecting the roads of this Province for your first tour of inspection. He has been travelling throughout the whole length and breadth of India and he naturally knows the state of road development in other Provinces better than I do, but if latter myself that he has chosen us, not because he himself is a Punjab Engineer but because he realises that here indeed you will have an opportunity of seeing the results of a well considered and well regulated programme of road development.

We can, with some pride, say that the Punjab has endeavoured to meet depression by overcoming it by carrying out such measures of development as its finances permitted. From 1926 onward we have added 1074 miles of metalled road and 563 miles of unmetalled road. I wish I could have added many more thousands of miles and connected up every village. It seems to me that if we are to undertake the opening out of village communications the whole road system of a district should come under the Buildings and Roads Branch. I am considering the possibilities of making an experiment in this direction.

We have done something in the matter of planting road-side trees. Our engineers are beginning to take a pride in their roads, and I am sure in a few years they will make our roads as attractive as possible. There is no reason why footpaths should not run under the shade of trees and foot passengers should not use these in preference to the hard surface of the road.

You Engineers are inclined, and quite naturally, to regard the Finance Department as your worst enemy, especially in times of financial stringency like the present and you probably find it difficult to impress on the man in the street that it is only the want of money that prevents you from providing the whole country with "Brookland Tracks", but you are always, or nearly always, on a sound track if you can imbue your Finance Department with the Bookies' Motto that "if you want to pick it up you've got to put it down". In this respect you will find that we have succeeded to some considerable extent. By persuading the Finance Department to "put it down" in the shape of money for surface treatment, we have enabled them "to pick it up" in savings on maintenance, and our only grievance is that they are reluctant to allow us to help ourselves to the "pickings" for further road development. The "pickings" are indeed considerable. As an instance I may mention that the maintenance of the road which you will see this afternoon has been reduced from Rs. 3,056 per mile before 1931 to Rs. 1,252 per mile since the completion of surface treatment. The extent of this saving throughout the province may be well imagined when I say that not only the Grand Trunk Road has now been surfaced from end to end throughout the Province but out of 2,719 miles of metalled roads we have tarred 2,123 miles and only 596 miles remain to be treated which we hope to complete in less than 2 years. I say this because, with the all too short a time which you are spending with us, you will be seeing only a very few samples, and the more suspicious of you may think that we are showing you only the best; but I can assure you that this is not the case and that the samples which you are seeing are typical of all our roads.

Road development needs funds and though at present the Government of India have not recognised the tax on petrol as a Provincial excise, collected at the Centre for the use of Provinces I can reasonably hope that as finances improve, the Government of India would pass on to the Provinces the whole of the revenue which motor traffic yields. Our province gives an income of Rs. 28,36,080 as follows from rural motor buses and does not include town motors :

	Rs.
Central	24,24,000
Provincial	1,51,500
Local	1,09,080
Miscellaneous	1,51,500
	28,36,080

The Road Fund which yielded a little over a crore in 1925 now yields 1¼ crores, showing an increase from 10 to 20 per cent.

With the introduction of the Central Road Fund we are all inclined to regard the Government of India and more especially Mr. Kenneth Mitchell as our "Fairy Godmother" but I suggest, now that you are all together for the next few days, by force of numbers you will persuade him to be a bit more liberal with his presents. I suppose you know that the 2 annas petrol tax (welcome as it is) is a drop in the ocean compared to the amount that the Government of India get in imports and excise from the motoring public of all our Provinces. We feel that far from looking a gift horse in the mouth we are justified in claiming a regiment of horses (in spite of the fact that horses don't like tarred roads!) the Government of India in 1925-26 realised only a revenue of 97 lakhs from excise and custom duty on petrol, now they get 4 crores and 44 lakhs.

As a layman I have no intention of dealing in technicalities before a gathering of experts but I would make one suggestion at the risk of offending any representative of foreign manufactures who may be present, and that is that in your searchings after knowledge you should endeavour as far as possible to concentrate on indigenous products of which there are many, and avoid the employment of imported preparations at the expense of the Indian markets.

In conclusion I wish you all success on your tour and your subsequent discussion in Delhi and I hope that this will be the first of a long useful series of annual gatherings.

5. Mr. Macfarlane then gave the party the following brief additional account of certain aspects of roads in the Punjab.

Our object in taking you along the Multan Road this morning was to show you an example of the serious problem with which we are faced of devising some form of road which will cater for heavily brick laden bullock traffic.

Our attention was recently invited to the successful treatment of the main road outside the railway station at Lucknow and Sir Jogendra Singh and I made a special inspection of this road at the kind invitation of the Chief Engineer, United Provinces.

The road, which is about two miles in length, is subjected to very heavy traffic and in many ways resembles the road which you have just seen approaching the Lahore railway station from Amritsar. It is actually 40 feet wide and when it was found necessary to renew the outer portions which had been subjected to very heavy wear and tear by bullock cart traffic they were replaced with cement concrete and it is found that the bullock cart traffic now rigidly adheres to these tracks which are 10 feet wide, leaving a centre of 20 feet for fast moving traffic.

It appears that the lesser tractive resistance, combined with the lighter colour of the cement, is an inducement to the bullocks to adhere to the tracks and travel one

behind the other in a straight line. I confess I was inclined to be sceptical about this and to believe that the picture which I was shown by the Cement Marketing Company of India as illustrating this was a fake, but our inspection definitely belied this.

We, therefore, intend to follow the example of the U. P. on the Multan Road, but, as we have succeeded in getting a 50 per cent. grant from the Reserve Fund solely on the ground that it is an experiment, the Government of India have agreed in the first instance to our constructing the track on one side only for the incoming traffic and seeing what happens.

On the advice of the Chief Engineer, U. P., we are, however, reducing the width of the track to 7 feet on the ground that this is sufficient, provided that the bullock carts follow one another and do not wander about the road.

I do not propose to enter here into the details of the construction beyond saying that we propose to construct it with six different specifications and that the question of sub-grade on a high made up embankment is one which requires some thought. I purposely refrain from going further in this not only for want of time, but because I see that there are several papers on this subject which will come up for discussion in Delhi.

To continue with the subject of bullock carts, proposals have been considered from time to time for the construction of entirely separate tracks for bullock carts parallel to main roads on the other side of the tree avenues, but these are very expensive involving entirely new bridge and culvert construction.

Also it must be realised that unless these tracks are metalled and tarred the dust nuisance is likely to be even greater than it is at present, specially with a light wind blowing across the road, and it is doubtful whether the inconvenience to traffic now caused by bullock carts adhering to the tarred surface is not counterbalanced by the dust nuisance when they travel on the berms. It would be interesting to know what experience other provinces have in this respect.

On our way into Lahore this morning we saw examples of pneumatic tyred bullock carts. I am sure you will agree with me that their universal adoption would solve one of our most difficult problems.

The Lahore Mall is an excellent example of a road which is confined to rubber tyred traffic and which in consequence has not been remetalled for nearly 20 years. Unfortunately I personally can see no way in which bullock cart owners can be induced to use rubber tyres unless perhaps the larger municipalities can be persuaded to encourage their use by inflicting a heavy wheel tax on carts which have not got them.

In the small descriptive pamphlet which will be handled round before your tour on December 8, I have referred briefly to the waviness of the Lyallpur Road between Buckeki and Shahdara.* This is an interesting feature to which I would invite the special attention of the members.

Before the introduction of surface treatment, roads were reconsolidated every 4 or 5 years depending on the rate at which they wore out. It followed, therefore, that there was a natural tendency for the road crust to increase in thickness as the years went on, but even where the surface has been scarified any unevenness due to previous settlement of the sub-grade has been corrected with new consolidation.

Now, however, once a new road has been constructed and treated with tar or any other surface treatment, it is seldom, if ever, reconsolidated. Any settlement in the sub-grade due to subsequent traffic or any other cause, therefore, remains as a permanency which it is impossible to cure without entire reconstruction.

The section to which I have just referred is a notable example of this and I am not at all sure that one of the remedies does not lie in constructing the brick soling coat as far ahead as possible and allowing the traffic to pass over it for a year or so before the wearing coat is added—at any rate in cases where the traffic is not excessive.

We have in the Punjab experience of certain cases where work has been stopped on account of financial stringency after soling coat only has been completed. Thus there are 3 miles of brick soling coat near Harike which has been done since 1930 and with the protection of a light layer of earth has shown practically no signs of wearing.

**Vide* para. 15 on page 281.

On the other hand, in a similar case in the Southern Punjab between Hissar and Sirsa where the soling coat has been open to traffic since 1929 it has worn very unevenly and very badly under fairly heavy lorry traffic and it is now a matter of urgent necessity to finish off the wearing coat otherwise the soling coat will have to be entirely replaced.

One item of general interest to which I would like to invite your attention is that of our efforts to cater for the convenience of the motoring public with regard to milestones, direction posts and so on and, although some of the engineers here present may have nothing to learn from these efforts, I hope I may be excused for referring to them.

In the first place we have earned the gratitude of the motoring public in recent years by turning all our milestones at right angles to the road, with distances marked clearly on both sides. Originally, these milestones were parallel to the direction of the road and although they were of use in old days when travelling in a tonga, they were very difficult to distinguish from a fast travelling car and it was quite impossible to do so at night.

I well remember the intense boredom not many years ago of doing a 100 mile drive at night without having the faintest idea where I was and being reduced to stopping every now and again to turn my head-lights on to a milestone.

You probably all know, the old chestnut about the man who asked the speed merchant who was driving him why he was being taken through a graveyard and received the reply: Those aren't tombstones they are milestones. Well, we cater for that type of driver by having especially large triangular milestones every 10 miles.

Then, again, opportunity has been taken of utilising empty tar barrels as parapets on curves. These have been whitewashed and are visible from a considerable distance with the head lights of a car and have been very instrumental in reducing accidents. The roads in our province are monotonously straight and drivers are often apt to get drowsy even in the daytime and are caught napping when after a long and straight stretch the road suddenly takes a bend.

I can remember that before tar barrels were available, I personally started the practice of whitewashing the dress on the outer side of the curves and was under the impression that the idea was entirely my own, but shortly afterwards when touring in France I found that this was the regular procedure along the *routes nationale.*

As regards direction posts, we have our own standard design of concrete post and signs, but we have recently made an arrangement with the A. A. N. I. who are displaying considerable activity themselves in this direction. A standard design has recently been drawn up, embodying our own concrete posts with the yellow enamel metalled sign boards supplied by them. They contribute to the cost of erection of these posts, the maintenance of which remains with us.

Their activities are of course mainly confined to the principal towns, but they are given the option of combining with us in the arrangement when any new sign-posts are to be erected. Experience has shown that the standard design still leaves a certain amount to be desired and as the arrangement has only just recently come into force members will not have had much opportunity of seeing the results on the route which they have hitherto traversed. I should greatly appreciate any advice on the subject.

We have had difficulty in the past with 'kacha' and unsightly sign-posts erected along our roads by local bodies and we have found that the only satisfactory solution is to take the law into our own hands and remove them and replace them with our own design.

A certain amount has been done with reflex signs for night traffic but these are of course very expensive. Moreover, as they have to be fixed at a low level to show off with a car head lights they have become disfigured by malicious people and in some cases the lenses have been stolen.

After crossing the Ravi Bridge this afternoon a large signpost will be seen at Shahadra which was specially designed by the Superintending Architect and which is electrically lit at night.

I would like to close by repeating what Sir Jogendra Singh has said about the pleasure which your visit is giving us and the pride that we feel that our province has been the first to be selected for your inspection. We are, I think, justly proud of our 2,700 odd miles of metalled roads and of the fact that 85 per cent of their length is surfaced. At the same time we realise that we have still a lot to learn and it is for this reason, amongst others, that we appreciate your visit and will gladly welcome in the course of our subsequent informal meetings any criticism or advice which any of you will kindly give.

6. **Mr. O. H. Tuelon, Chief Engineer, Burma, proposed a vote of thanks on behalf of the members to Sir Jogendra Singh and Mr. Macfarlane in the following terms :—**

Gentlemen, As one of the representatives of the most distant Province of the Indian Empire, and one that is likely shortly to cut adrift from that Empire, I have been given the privilege of proposing a vote of thanks to our most kind and thoughtful host the Hon'ble Minister for Agriculture Sir Jogendra Singh for the way in which he has attended to our intellectual and physical well being.

When in April 1933 I was sent to the Road—Rail Conference at Simla I had the pleasure of listening to Sir Jogendra Singh's eloquent speeches made in the interests of the Government he serves so well. One could not listen to those speeches without becoming deeply interested in all that was being done in the matter of developing communications in the Punjab.

I never expected however that I should one day have the opportunity of seeing for myself the works of the Punjab Engineers about which I had heard so much.

I must own that when the proposal to hold an All-India Road Congress was first suggested we in Burma were inclined to think that the conditions in that Province would make it impossible for delegates from Burma to attend. However thanks to the genius of that Master of Co-operation and Co-ordination, Mr. K. G. Mitchell, the difficulty has been overcome by the Central Government coming to the rescue of the Provincial Governments in the matter of providing funds to cover the cost of the T. A. of the official delegates.

It is in consequence of this that I now find myself proposing our most grateful thanks to our kind host the Hon'ble Minister for the cordial manner in which he has entertained us and to Mr. Macfarlane and his Staff for the trouble which they have taken in showing us so much of the road work in the Province.

The health of Sir Jogendra Singh was drunk with musical honours.

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7. At about 2-30 P.M. the party left Lahore for Kathala and arrived there between 4 and 5 P.M. Rai Bahadur Sant Ram, Superintending Engineer and Mr. R. L. Sondhi Executive Engineer, accompanied the party up to Kathala. The special train left Kathala during the night. The following information was furnished in respect of this section of the G. T. road.

WEDNESDAY AFTERNOON, DECEMBER THE 5TH.

Grand Trunk Road,—Lahore to Kathala.—At mile 0 opposite the Government College where several roads meet an experiment is being made with an island platform to regulate the traffic. The proposed platform has so far been delineated with tar barrels only with a view to watching the effects. The Punjab Government has under consideration a proposal for the erection of such island platforms elsewhere in Lahore and other centres with a view to reducing the number of constables on point-duty.

After passing the new Lady Willingdon Maternity Hospital and the Fort (on the right) and the Chota Ravi, a separate water bound macadam road will be seen on the left for bullock-cart and animal traffic. From the end of the track to the Ravi bridge the cattle traffic is, at times, extremely heavy.

The River Ravi is crossed by a road bridge shortly after leaving Lahore. The width of this bridge between wheelguards is 18′ only and is far too narrow for the congested traffic; but unfortunately the design of the main girders does not permit of further widening. The bridge was constructed in 1914-15 and replaced an old boat bridge further down stream. It consists of a water bound tar-surfaced road on iron troughing supported on 97′ span lattice girders, the piers being supported on single octagonal brick wells sunk to an average depth of 70′ below bed level.

After passing Shahdara (with Jehangir's tomb in the distance on the right) the road is reduced to its normal width of 12 feet. It consists throughout of water bound stone macadam with tar surfacing. In certain isolated lengths experiments have been made with emulsions but no conclusive results have been drawn. The tar surfacing is renewed on an average about once every 18 months.

The traffic on the 40 mile stretch between Lahore and Gujranwala is very intense reaching as much as 350 tons per yard width per day in the vicinity of Gujranwala.

The soil in many portions of this section is very sandy and impregnated with saltpetre. Considerable difficulty is, therefore, experienced in maintaining the berms in a satisfactory condition. This is particularly evident between miles 16 and 20 in the neighbourhood of Muridke where the sudden drop from the metalled edge to the level of the berm is considerable and is a source of danger to fast moving traffic. Successful experiments have been made in miles 63 and 64 by providing a layer of good firm earth watered and rolled, but the cost is too high to enable this procedure to be followed throughout the entire length of the road.

The metalled surface in the last furlong of mile 43 has been provided with brick edging to give a uniform appearance. This costs about Rs. 400 per mile and the practice is being continued in cases of new construction elsewhere.

The road bridge across the Chenab River is met in mile 65, *i.e.*, shortly after passing Wazirabad. This bridge was completed in 1922 and replaced the old train ferry. Its construction marked the completion of through bridged communication between Delhi and Attock. The width between wheel-guards is 22 feet and the traffic facilities offered by the additional width of 4 feet to that of the Ravi Bridge is very noticeable. The roadway consists of precast reinforced concrete slabs 6 feet in length resting direct on cantilevered rolled steel beams supported on lattice girders 142′ c to c. The piers are supported on single circular brick wells sunk to an average depth of 90′ below bed level.

8. The party arrived at Attock station at about 9.15 where they were met by Mr. W. T. Everall, Deputy Chief Engineer, Bridges, Mr. A. S. Hay, Executive Engineer, Bridges, and Mr. W. E. Gelson, Assistant Bridge Engineer, N. W. Rly; and also by the following officers of the North West Frontier Province:

Mr. F. H. Burkitt, Chief Engineer.

Mr. A. Oram, Superintending Engineer.

Mr. G. A. M. Brown, Superintending Engineer.

Capt. Lang Anderson, R. E.

Capt. J. R. L. Owen, R. E.

Capt. Robinson, R.E., and

Rai Sahib L Kirpa Ram, Assistant Engineer.

Mr. Everall very kindly explained to the party the reconstruction and regirdering of the Attock Bridge, with the assistance of a model and photographs, as follows:

"The reconstruction of the Bridge was undertaken during 1925—29. The original bridge was designed by the late Sir Guilford Molesworth and was completed in 1883. The photograph [not printed] shows the structure as it was prior to 1925. The bridge was supported on steel trestle piers founded on the bed rock and on masonry abutments. Massive masonry cutwaters were provided on the upstream side of the trestles to protect them from floating debris during the periods of high water. The photographs on the board show in a general way how the original bridge was erected. The three 250 feet land spans were built from direct staging and the two 300 feet river spans were erected on timber fan staging using the weight of the adjacent land spans for counterbalance.

Railway and Road traffic had so increased by 1921 that the steelwork was already overstressed under the comparatively light trains then in use and could not safely deal with modern main line traffic. Reconstruction of the bridge was therefore taken in hand towards the end of 1925 and was completed in the autumn of 1929. The strengthening scheme consisted of the replacement of the two river spans by new steel main girders erected outside the old ones and supported on concrete piers built up round the old trestles. The girders are spaced at 28 feet centres and the clearances are such that a double track can be provided at a future date by duplicating the girders and re-arranging the railway flooring system. For the three 250 feet spans the old main girders were converted to continuous girders by the erection of a central pier at each span, reinforcing the members where necessary, and remodelling the floor-system to suit the new loading.

I propose to describe the foundation and pier work first. The construction of the foundations for the pier in midstream which rests on a partly submerged island presented the most difficult problem connected with the sub structure work. It was

solved by first constructing a cofferdam of 15×5 steel sheet piling on the submerged portion of the island. Soundings revealed that no lateral support could be obtained for these piles from the rock bed as the rock profile is extremely irregular. An inner and an outer shell of piles divided into chambers filled with cement concrete was therefore used and a system of steel framing served as a guide and lateral support for the inner row of piles. This frame was bolted to a plate girder 54 ft. long which was connected to 4 anchors deeply embedded in concrete. While these sheet piles were being driven, excavation for a large part of the foundation of the pier was proceeding. It was considered that to attempt to excavate the whole area of the foundation simultaneously might lead to the sudden collapse of the coffer-dam which, when foundation level had been attained, would be subjected to a pressure head of 8 to 9 ft. of water. The excavation was therefore carried on in 6 ft. strips working from the outside towards the centre of the pier. Alternate strips were excavated, and a chamber at the end of each strip was provided with a pair of vertical grooves so that, should any serious leakage occur through the coffer-dam, a shutter could be let down into them and plugged. Two large centrifugal pumps were used to test the coffer-dam for watertightness, and after certain subterranean channels had been plugged with concrete, the dam was dewatered and the cement concrete was placed up to the level of the pier base. Features of this work are shown in the model.

Cement of Indian manufacture which complied with the British Standard specification was used throughout the work. Sand was obtained from Lawrencepur, 21 miles from Attock, as the local sand is unsuitable. On account of the large quantities of sand, shingle and broken stone required for the work, chutes were erected at each end of the bridge. The aggregates were loaded in hopper-trucks, and full train loads were conveyed to the bridge site and unloaded through these chutes which were so designed that by manipulation of trap-doors sand and coarse aggregate could be discharged in separate heaps. Cement in bags was also dealt with by chutes in dry weather. The excavation for the piers was carried down well into the bed rock and this was filled with 1 : $2\frac{1}{2}$: 5 cement concrete with 15 per cent of boulder plums. The foundations for the three new intermediate piers built under the centre of the three shorter spans and those for the 2nd and 4th main piers presented no difficulty. The pier superstructures are built with an outer skin of precast cement concrete blocks in one ton units made at site in special blockyards on both river banks with a hearting of 1 : 3 : 6 mass concrete containing thirty per cent of boulder plums. Temporary jib cranes attached to the girder end posts and worked by pneumatic power were used for hoisting materials for pier construction.

Regarding the steelwork—the three shorter spans were converted into continuous girders, the central re-action being settled and adjusted experimentally by means of Calibrated Hydraulic Jacks and the new central bearings were set at such an elevation that the total shear due to dead load, live and impact was redistributed so as to minimise the necessary stiffening of the web members towards the ends of the spans which were supported by direct staging of standard interchangeable type during the time the main girders were being remodelled. Only the rail flooring system required strengthening on these spans which was done by reinforcing the existing cross girders and replacing the rail bearers.

Erection of two new 300 ft. river spans by cantilevering each half span—The anchor arms for cantilevering the shore ends of each span were provided by the adjacent land spans. The other ends were erected from the island pier so that one half balanced the other during erection. Temporary connections between adjacent spans were made by steelwork specially designed and fabricated to be immediately available for new small railway bridge spans on completion of the Attock steelwork erection. Two special bridge erection cranes operating from the railway track on the old girders were used for building the cantilevers, which were erected connected at mid span and converted to simple trusses before the old work was interfered with. The complete main span in the model shows the old span still in place inside the new structure.

Having reached the stage when the new main girders and cross girders had been assembled, the weight of the old spans was transferred by jacks to the new work and the old rail bearers were replaced by new ones. The old steelwork was then cut into convenient lengths, when top booms and web system were removed, leaving only the old bottom booms and old roadway. All this work was done under traffic during restricted periods when the bridge was blocked for the passage of trains.

I will now describe how the new highway floor was erected on the main river spans. Owing to the volume of road traffic it was possible to block the road on the

bridge for only 3 consecutive hours during daylight, and this period was chosen to coincide with the longest blockperiod for rail-traffic. A general arrangement of the scheme for changing the highway floor is shown on the tracing. Two movable steel ramps with trough and timber decking were erected on the old highway over the island pier during the night, when the bridge is closed to road traffic. Each lower chord of the old spans was divided into five sections by cutting out the rivets in four main joints, some of the holes being refilled by service bolts. The ramp on one main span was rolled back during the first road block far enough to disclose the first section of old roadway which was then freed from the adjacent flooring. Two 25-ton cranes lifted the first section of old floor to the level of the temporary ramps. The new road stringers were then skidded laterally into their final position on new road cross frames under the old roadway, and the weight of the raised section of old roadway was transferred to them, by temporary packings. The handrailing and wheelguards were then made good to pass traffic until the next block, when a similar section of the other main span was dealt with in the same way. The road-troughing was slid into position from outside, and the concreting was carried out under the old work. The old roadway was then finally removed in sections the ramps being rolled towards each other and finally meeting again over the island pier.

The concrete roadway was made up in sections 6 feet in length and the full width of the roadway, the joint between adjacent sections being filled with malthoid fabric. It was found necessary to limit the length of the concrete sections owing to the tension and dynamic effects set up by the bottom chords due to passing trains.

This is a matter of some interest for bridges carrying combined loads and where the roadway is suspended from the bottom chords, because, if the concrete is made in sections of too great a length, we have found that the concrete invariably cracks, and there is an example of this in the flooring of the first span where we started off with the slabs of a considerable length with the result that concrete sections are badly cracked, but after reducing the lengths to a matter of some 6 ft. to suit the centres of the existing cross girders, no further trouble was experienced.

The concrete surfacing is of 1: 2: 4 proportion. It was mixed in 1/2 yard Ransome Air Driven machines erected on temporary platforms above the piers. The concrete was conveyed and deposited by hand and cured for 14 days.

FLOODS.—In the latter part of the summer of 1928, when the service staging was completely erected under the 257 ft. spans, the great Shyok dam glacier, situated in the Karakoram range of hills, some 600 miles from Attock, was reported as being in imminent danger of bursting, and it was expected that the release of the pent-up water would give a rise of 30 feet at the Attock Bridge.

The staging under the 257 ft. spans of the bridge was therefore dismantled in July. High floods did not however occur that season; but it was realized that the dam would probably fail during the following summer, and the work was arranged with the object of completing the whole of the girderwork during the low-water season between October and April, and removing all the staging and erection-gear out of the danger zone, before the river began to rise. The steelwork for the new 304 foot spans arrived at site in October and November, and the main steelwork was erected and riveted and the erection gear and temporary structure were removed from the flood-area zone before the end of March, 1929.

The glacier dam broke during August, 1929. It was approximately 4,000 feet long and 490 feet high, and had formed a lake 12 to 14 miles long and ranging from 1 to 3 miles wide. The flood reached Attock in the early morning of the 16th August and rose to a height only 2½ feet below the previous maximum recorded level of the 29th July, 1882, with a discharge of 841,478 cusecs and a mean velocity of 16 feet per second. On the 28th and 29th August, floods in the Indus valley synchronized with floods in the Kabul and Haro rivers, with the result that at Attock the water rose 41 feet above the ordinary monsoon level and 61 feet above the low winter level; this is 6 feet above any previously recorded height. During the period of maximum discharge both the Haro and the Kabul rivers were also in high flood, and considerable heading up of the water occurred in the gorge, as the Haro river runs in lower down. The Executive Engineer of the Discharge Division of the Punjab Irrigation Department estimated that, when the river was running at its maximum on the 28th August, the discharge was 817,000 cusecs, and an average velocity of 13.2 feet per second. The afflux at piers Nos 2 and 3 was 5 feet.

While the river was in high flood, the bridge was being tested by trains running up to 40 miles per hour. The contour of the nose of the piers causing an afflux of 5 feet proved very successful in deflecting large floating timbers, which scarcely came in contact with the piers.

An abnormal flood in the Indus took place in June, 1841. Captain Mackesen, then Political Officer at Peshawar, reported that rumours were prevalent that the course of the Indus in the mountains in the regions of Nanga Parbat had been interrupted by a landslide; and, although the discharge was abnormally low, little credit was attached to the rumours. However, between the 10th and 12th June of that year, the river broke through and a lake 40 miles in length, 1,000 feet deep, and several miles in width was released in 48 hours. All the country near the Attock gorge, to 40 miles away and within 10 miles of Peshawar, was overflooded, and the river was reported to have risen 80 feet in the Attock gorge. Many towns and villages were completely swept away, and there was a heavy loss of life.

The entire work was carried out by the Bridge Branch of the North Western Railway and the Executive Engineers in charge were Mr. T. Bingham, from commencement until March, 1928 and from that period until the completion of the bridge in August 1929, Mr. A. S. Hay who is with us to-day. Mr. Gelson, who is also here, was the engineer in-charge of the erection of the steelwork.

A word about the cost of the work, which totalled nearly Rs. 25·00 lakhs, divided as follows :—

	Lakhs.
Pier work	10·25
Girder work	11.00
Tools and Plant	1·75
General charges	1·90

The total cost was slightly in excess of the original estimate.

A few copies of my paper No. 4767 which was read before the Institution of the Civil Engineers (London) on the reconstruction of the bridge, are available with me for distribution if any members care to have them."

9. After Mr. Everall's lecture the party went down the river bed and inspected the concrete work and foundations of the bridge. before leaving Attock notes and memoranda on the roads to be visited and the points of interest to be noted in the North-West Frontier were given to all members. These are reproduced at Appendix AI.

10. The party left Attock at 10-15 A.M. and after stopping at Khora, where the Sappers and Miners were launching a "Meccano" span as part of their training, examined various points of interest referred to in the notes.

11. The pneumatic tyred and iron tyred experimental tracks in mile 267 were most interesting. Two identical tracks had been consolidated and on one there were two iron tyred bullock carts each 2,500 lbs. of stone and on the other two rubber tyred bullock carts carrying each 5,000 lbs. of stone. The latter appeared to travel faster and with less effort. The track under rubber tyres appeared to be undamaged but the other had been badly worn.

12. In the afternoon the party travelled *via* the Adozai Bridge to the Gandab Road and back returning *via* the Michni Road *vide* items 2, 3 and 4 of Appendix AI.

13. Returning to Peshawar at about 5-30 the whole party then attended a lecture at the Peshawar Club by Lt.-Col. Wakely describing the road up the Khyber Pass. After Col. Wakely's lecture, Mr. Powell, Chief Engineer, Bihar and Orissa, thanked Col. Wakely for his lecture and the remarkable arrangements made for the whole party both on the road and at the railway station.

14. On the following day the party left Peshawar in the morning and visited the roads up the Khyber Pass which were explained by Col. Wakely. They also

inspected the road-builder and compressor described in item 7 of Appendix AI. On the return journey they visited the soil stabilisation experiments at Garhi Hassan (item 8, Appendix AI) and after seeing the plant described in item 9 and certain earth roads in the locality, returned to Peshawar.

15. The special train left Peshawar on the evening of the 7th and arrived at Lyallpur at 9-20 A.M. on December the 8th where the party was met by Sardar Bahadur Gurbaksh Singh, Superintending Engineer, and Mr. H. A. Harris, Executive Engineer, Lyallpur. The party proceeded in cars from Lyallpur to the Jaranwala *Mandi* and thence along the Lyallpur-Lahore Road to Lahore, the following description of the road having been issued to members in advance.

Lyallpur-Lahore Road.—This road is of particular interest as it affords several examples of departure from the usual specification of tar-surfaced water bound macadam which has been adopted throughout the province. Details of the various types of road are given below:—

Miles.	Soling.	Wearing Coat.	Last date of consolidation.	Average interval of resurfacing.
85—66	Sangla Hill Stone.	Water bound limestone with tar surfacing.	1930-31	1½—2 years.
65—46	4½" brick	Ditto ditto	1928-31	1—1½ years.
45	"	Limestone with tar and pitch grouting.	1928	1½—2 years.*
44	"	Brick ballast with tar and pitch grouting.	1928	2 years (last surfaced in October 1932).
43—39	"	Water bound limestone with tar surfacing.	1928	Ditto.
38—23	"	31 Brick ballast with bitumen penetration.	1927	Resurfaced in 1932 and 1933 only.†
22—7	"	Water bound limestone with tar surfacing.	1928-29	One year.

The portion between Bucheki (mile 50) and Shahdara (mile 5) was originally constructed to its present specification between 1927 and 1929. It will be noticed, more especially when travelling at high speed, that the surface is distinctly waved. This is due to some extent to the fact that the sub-grade has settled unevenly, there being no means of rectifying this defect with subsequent consolidation as has been possible in the past on other roads where water bound macadam has been replaced with fresh consolidation.

16. Near the Jaranwala *Mandi* the party inspected about half a mile of concrete trackways laid on earth road which were of considerable interest *vide* Appendix AII.

17. The party arrived in Lahore in time for lunch and the official portion of the tour then concluded, the members being free in the afternoon. The special train left Lahore at 10 P.M. and arrived in Delhi on the morning of Sunday, the 9th December.

* Cost about Rs. 1,000 per mile more than tar surfaced water bound macadam.

† Cost about Rs. 2,000 per mile more than tar surfaced water bound macadam.

APPENDIX A-I.

INDIAN ROADS CONGRESS 1934—TOUR OF INSPECTION IN THE NORTH WEST FRONTIER PROVINCE.

ITEM 1.—GRAND TRUNK ROAD.

There is nothing of special interest to note along this stretch of the road. Generally it is in a satisfactory condition with a good motoring surface.

Width.—After the Punjab section on the other side of Attock Bridge it will be noticed that the width has been increased from 12 feet to 16 feet. This is an improvement from every point of view. There is a greater sense of security while driving and the intensity of traffic loading is decreased. The latter is an important point as it has been experienced on the Nowshera-Mardan road that while the part which is 16 feet wide is in good condition that which is 12 feet wide is a constant source of trouble.

Surfacing.—10 miles of the above stretch of the Grand Trunk Road have been surfaced with ¾" premix tar mats, the remaining 11 being water bound macadam with tar surface painting. Most of the mats were laid in 1932-33 and are therefore 2 years old and it is hoped will not need renewal for some years. Very little patch repairing has been needed on these miles.

The other miles were mostly remetalled (and widened at the same time) in 1930, 1931 and 1932 and tar surfaced. On an average they are 3 years old. They have needed occasional patch repairing and on an average have been resurfaced with tar every 2 years.

Traffic.—The intensity of traffic varies from 150 tons to 350 tons per yard width per day.

Nowshera to Peshawar.

Traffic.—Here the traffic intensity increases to 350 tons and up to nearly 1,000 tons per yard width per mile (for 2 miles or so near Peshawar).

General.—The surface on this stretch does not compare with the stretch just passed over. It is generally uneven, but efforts are being and have been made to improve this. The use of straight edges, in addition to camber forms is producing better results, and the marking of pools of water after rain has also been resorted to with success.

Very heavy bullock cart traffic is experienced. Notices have existed for years stating that the maximum load is 25 maunds, but loads up to 65 maunds per bullock cart are frequent. The notices are not apparently legally enforceable and it has been suggested that the Local Government should legislate in order to save the roads such an excessive burden. The following are items of interest and halts at these points are proposed :—

(1) *Experimental work on miles 259, and 260 near Pabbi village.*

1st half Mile 259 . . .	(1) ¾" premix tar mat on scarified and regarded subgrade.	Completed September 1934.
2nd half Mile 259 . . .	(2) Water bound macadam with tar surfacing painting.	
Mile 260	(3) 1½" premix tar mat.	

(2) *Pneumatic Tyred and Iron Tyred Bullock Cart experimental tracks. Mile 267.*

The object is to obtain comparative data on the effect of bullock cart traffic on road surfaces. The possibility of a subsidy to assist bullock cart owners to fit pneumatic tyres is under consideration. It may be noted that the section carrying iron-tyred carts broke up rapidly and had to be repaired while the pneumatic tyred section is intact. Experiment started 9th October 1934.

(3) *Failure of 1½" Premix Tar Carpet. Mile 272.*

Mat laid in 1933 (June). Water not used during consolidation. Has rutted badly and ruts have been repaired without much success. It is questionable whether thick mats, premixed with tar, are a successful proposition. The provision of side support is probably essential.

(4) *Remetalling and surfacing part of mile 273.*

For some time trouble has been experienced on this mile which carries heavily loaded bullock carts in very large numbers. Various specifications have been tried without success. Rutting and pot-holing has invariably resulted within 6 months. It was stated that the foundation was on made-ground and subject to water logging due to the close proximity of surface water. The water surface of a well close by is at least 8 feet below the foundation of the road. Trial pits were dug through the road and 18 inches of concrete-like water bound macadam on 3" of shingle were found. There are no soling stones. However 18" of water-bound macadam should make an excellent foundation for any road. Here the proposed work, now in hand, is :—

(1) Widening from 16 feet to 30 feet.

(2) Providing kerb-stones to give side support.

(3) Removal of old carpet, scarifying lightly the sub-grade and reconsolidating with 4½" of new metal.

(4) Surfacing with an armour coat of ¾" chippings premixed with Bitumuls.

(5) *3 furlongs of concrete Road, with ¾" chippings premixed with Bitumuls.*

The concrete here was laid in 1933 as an experiment. The method was that of laying the dry-mix in place and watering and consolidating. This method obviously requires knowledge and experience and, in any case, appears to be of very doubtful advantage. It has not been a success, having pot-holed badly. The new surfacing consists of 1½ furlongs of Colas and 1½ furlongs of tar premixed ¾" mats. The Colas being on the first half of the section. The object is to compare Colas with tar.

Berms.—The policy followed is to attempt to make the berms safe for motoring in all weathers and as far as possible dust proof. Shingling and the use of scarified metal is resorted to whenever possible.

Records.—A system of records has been started this year in which the actual costs of special repairs and the average costs of maintenance of each mile are inserted on the completion of work and at the end of the financial year, respectively.

COSTS.

Grand Trunk Road miles 262—275 (14 miles of the most heavily loaded road in the Province).

From records available the following figures are interesting :—

(a) *Special Repairs, Remetalling and Resurfacing.*

(i) 3 years (1925 to 1928) before tarring was started : Rs. 2,850 per mile per year.

(ii) 4 years (1930 to 1934) after the transition period (1928 to 1930) from water bound macadam to tarring and after widening 12′ to 16′: Rs. 2,400 per mile per year.

(iii) The cost of maintenance averaged Rs. 700 per mile per year, for whole period 1925-34.

(iv) The expenditure this year (1934-35) on 47 miles Attock to Peshawar will amount to :—

Special Repairs.—Rs. 82,800, or Rs. 1,760 per mile.

Maintenance.—Rs. 19,200, or Rs. 410 per mile.

Total Repairs and Maintenance.—Rs. 2,170 per mile.

(b) *Tar surfacing.*

	Per mile 16 feet wide. Rs.
(i) First coat tar on water bound macadam	2,400
(ii) Second and subsequent coats	1,600

(c) *¾" premixed mats.*

including seal coat	5,000

ITEM 2.—MICHNI ROAD.

Miles 2, 3, 4, 5, 7, 12, 14, 15 and 16 to 23 are all pre-mix Tar mats (1½—2"). Miles 9 and 13 are water bound Macadam tar painted. It will be noticed that miles 6, 8, 10 and 11 are untreated and in poor condition. The policy here is to maintain the good miles and if necessary let the bad miles go. Next year it is proposed to remetal and tar these four miles.

The Kabul River is crossed by 2 bridges. The second pier of the second bridge gave trouble in 1930 through scouring of the pier Sheet piling was put in. The other piers are liable to give similar trouble.

ITEM 3.—GANDAB ROAD.

This is a two way unmetalled motor road stablised with gravel. The following stops will be made—

(1) *At Dand.*—The descent into the nullah was done in two days by lining the cliffs with explosive. It was an urgent military necessity to get through quickly to Dand Camp. The alignment of the ascent is capable of improvement, but time did not permit any better alignment during the operations. A bridge here would be an advantage, but time of erection was prohibitive.

(2) *Top of Dand Pass.*—Looking back you see the general nature of the ascent. Note original path and remains of camel road. Camels were tried before the camel road was improved and they reached this place in 2 hours from Camp, killing 2 camels.

(3) *Gandab Nullah.*—Site of water Supply Station for Camp Rattray. Lift 500 feet. Length of pipe line 3½ miles. Installation of this Water Supply saved one Battalion.

(4) *Buddhist Alignment.*—An old road discovered by the C. R. E. Probably made 2000 years ago and in use up to 100 years ago. A good idea of the general nature of the country and its difficulties is given from this point.

(5) *The Karappa.*—View of the Promised Land. We would have done better by coming up the other side with the road, but it was impossible as we would have killed many camels and mules with the blasting.

NOTE.—The causeways, which are of special design, are being lengthened to take a 15 foot flood.

NOTES ON THE MOHAMAND ROAD.

1. The road was constructed from Pir Kala on the Peshawar-Shabkadar road through Hafiz Kor and Dand to Ghalanai and 6 miles beyond that place.

2. Total length—20 miles. It goes right through the Lower Mohmand country.

3 The road was constructed in two main stages—

First : A motorable road 14′ wide without bridges,

Second : A 2-way motor road 22′ wide bridged

Time of construction. first stage—

Pir Kala to Dand	7 miles	3 days,
Dand to Ghalanai	7 miles	28 days.
Ghalanai to Yusuf Khel	6 miles	3 days,
Total .	20 miles	in 34 days

Second Stage—

20 miles in a further 30 days, or 64 days in all.

There are 150 bridges and culverts; but no bridge more than 21′ span.

Reasons for high speed of construction were the rapid and good organisation of the work, and the large amount of modern machinery used.

4. *Organisation.*—The work was done under the direction of the C. R. E. Peshawar District who had a staff of 1 Field Engineer, 4 Asstt. Field Engineers and 2 Companies K. G. O. Bengal Sappers and Miners. The total works staff consisted of 3 Sub-Divisional Officers, 24 Overseers and 23 Works Munshis together with the necessary Office Staff. The Stores organisation was worked from Peshawar and included the Advanced Engineer Park and the M. E. S. Workshops at that place and the M. E. S. Saw Mills at Nowshera.

5. Transport used—about 80 lorries per day.

6. Tools issued about 30,000 of all kinds.

7. Explosives used—About 26 tons of Gunpowder, Gelignite, Dynamite and Guncotton. Detonators 25,000 and about 24 miles of safety fuze.

8. Between 5,000 and 6,000 men were employed continuously by contractors, the Field Engineer and the Sappers and Miners. There were 6 road contractors, each being given a section and 3 Bridge Contractors. Each contractor had one labour camp which was guarded by local armed tribesmen.

9. Road machinery used—

3 Tractors.	50 pumps of various kinds.
2 graders.	6 drag brooms.
1 auto-patrol.	6 road scrapers.
4 compressors.	1 fire engine.
1 scraper.	1 steam water cart.
4 steam rollers.	20 lorry water carts.

ITEM 4.—ADOZAI BRIDGE.

Completed 1930. Vibro pile piers. Driven 21′ below cap level, an average of 16′ below bed level. Piers No. 6, 7, and 8 (from Peshawar end) were scoured out in July 1932, Depth of scour 25′. M. E. S. considered that the cause was partly lack of waterway and accordingly the bridge was lengthened by 180 ft.

Five piers Nos. 23, 24, 25, 26 and 27 were scoured out in July 1934. These were 5 out of the 6 new piers in the extension. The river in a period of under 3 weeks changed the alignment of its deep bed from one side to the other of the river bed.

The proposals for repair and improvement are :—

(1) To retain 21 bays, *i.e.*, practically what remains of the bridge.

(2) To put a floor in this length to protect the piles from under scour, roughly following the usual practice in weir design.

(3) To provide guide bunds to flume the river and reduce concentration, the road on each flank being raised to guide bund level.

Alternatives are—

(1) A new bridge at a new site with either a weir type of foundations or with deep well foundations.

(2) A new bridge at the same site on deep well foundations.

As regards deep well foundations, the calculated depth of scour is 35′, so that, to be safe, the wells (or piles) would have to go down 50′. The sinking of such wells would only be possible by the use of caissons and compressed air which would be prohibitively expensive.

A discussion at site is proposed and members are invited to express their views on the problem

Item 6.—The Khyber Road.

A. Peshawar to Jamrud 9 miles.

1. This section is Cis-Frontier.

All these 9 miles are treated with Colas.

2. Mile 4 has recently been remetalled and surfaced with Tar. A seal coat of Colas will later be applied; the idea being to obtain the advantages of the greater penetration of the Tar and avoiding the disadvantages of a Tar surface, namely eventual "dying" (evaporation of essential oils) by means of the cold emulsion.

3. On the first four miles there is very heavy bullock cart traffic on the right hand side of the road only. Carts coming into Peshawar carry full loads and go out empty. It is suggested that the right half of the road should have a higher specification than the left because of this. The frontier is crossed at Jamrud.

B. The Khyber Road from Jamrud to Landikhana.

1. There are two roads and a railway between Jamrud and Landikhana. The North road is the motor road and the South road is the caravan road.

The carvan traffic is very heavy and it would create impossible traffic conditions if this traffic used the motor road. In two or three places the two roads coincide, and 24 feet width is given at these places.

2. The North road is a two way surfaced road 16′ wide metalling.

Practically the whole road is Colas surface painting. It carries chiefly motor traffic and no bullock cart traffic. Mile 26 is Bitumuls painting and Miles 27 and 28 are Tar Premix laid in 1933.

3. Very considerable savings have been made in the maintenance estimates on this road by the provision of proper drainage, and by Colas painting. By proper drainage is meant the construction of new retaining walls where slips occurred, enlargement of existing culverts and the provision of new ones, and the enlargement of roadside drains.

Previous to 1931, the annual maintenance costs were Rs. 3,000 per mile per year, and now they are Rs. 1,500 per mile per year, and the road is about three times as good as before.

We consider that half the savings are due to painting and half to improved drainage.

4. Other improvements made recently are the provision of 3 new bridges at Katakushta and Zintara, the large re-alignment in Mile 15 and many smaller re-alignments and widening.

In 1926 it took nearly two hours to motor from Peshawar to Landi Kotal, and now the journey can be done in 45 minutes.

5. Halts are suggested at the following places :—

1. *Mile 15.*—At the top of the new retaining wall. Cost of this re-alignment was Rs. 15,000. The two reversing stations on the railway can be seen and a good view of the two roads is obtained.
2. *Ali Masjid.*—The entrance to Alimasjid Gorge. The Fort is seen above. It is said that whoever holds Alimasjid Fort holds the Khyber. There have been many fights for these impregnable heights.
3. *Michni Kandao.*—A fine view over the Hindukush range is obtained. Char Bagh Fort is seen on the left and in the foreground below is the old Landikhana Camp. The white house in the distance is the Afghan Post Office at Torkham.

Item 7.—Road Builder and Compressor.

The Road builder outfit consists of a "Caterpillar" 50 H. P. Diesel tractor with a Laplant-Choate trail builder attachment fitted to it. This is a stout steel blade which can be fixed either straight across, or on a slant with the right-hand end leading, or with the left-hand end leading. It can also be tilted in the vertical plane. The whole of the blade carrier frame is pivoted about a horizontal transverse axis near

the centre of gravity of the tractor so that the blade can be raise or lowered to take a cut below the level of the tractor itself. The raising and lowering mechanism is hydraulically operated by means of an auxiliary oil pump driven by gearing off the tractor engine. This type of machine is comparatively new in India, the first two, one 50 H. P. and one 35 H. P., being received in Peshawar District in November 1933. They have fully proved their usefulness.

The road-builder can be used for cutting out a new road along a hillside. It can also be used for widening an existing road. You will see it employed on the latter kind of work on an unmetalled cart road near Landikotal. The amount of work done by these machines varies according to the nature of the work and the hardness of the earth or rock. As a general guide the following figures may be taken for the output of a 50-H. P. road-builder in an 8 hour day :—

	cu. ft.
(i) Clay soil 30° slop	60,000
(ii) Mixed earth and stones	30,000
(iii) Conglomerate	25,000
(iv) Half soft and hard rock not requiring blasting	16,000
(v) 75 per cent. hard rock not requiring blasting and 25 per cent. soft	8,000

The 35-H. P., road-builder will do half the output of the 50-H. P., but it cannot do anything more than soft rock work.

For further details of method of working etc., see Technical Paper No. 10 issued by the Engineer-in-Chief, Army Headquarters, Simla.

This portable compressor set made by Holman & Co., Camborne, England has several interesting features.

The *compressor* itself is of the Hele-Shaw rotary type, very compact and efficient for its output, which is 130 c.ft. of free air per minute. This is sufficient to run 3 *medium-sized pneumatic drills under ordinary conditions, or 2 if the air piping is long* or the work is very heavy.

The *engine* is a 36-B. H. P., Dorman cold starting high speed diesel engine. The fuel consumption for ordinary running on this type of work is about 11 lbs. of diesel oil per hour, which costs us (*i.e.*, M. E. S.) 5 annas per hour, at the price of Rs. 63 per ton.

The *carriage* is specially designed with pneumatic tyres and motor car type springing so that it can be towed at speeds up to 20 m. p. h. on a good road. It is also easy to handle over bad ground. This particular machine has been made with a special experimental design of axle and wheel attachment to enable it to be man-handled over mountain paths. The wheels can be fixed in an alternative position inside the frame of the carriage, thus giving a very narrow wheel track. By the employment of an adequate number of coolies on drag ropes, this machine can be taken almost anywhere a laden pack mule can go.

ITEM 8.—EXPERIMENTAL SURFACING AT GARHI HASSAN.

1. The object of this experiment was to find out the methods and materials most suitable for treating a natural clay sub-grade with bituminous compounds.

It was desired to find out :—

(*i*) Whether a clay subgrade could be stabilised without soling and metalling, and whether the treatment given would stand up to traffic.

(*ii*) A rapid method of treatment with a view to road construction during military operations using materials locally available.

2. The stretch of road chosen was from the North Circular Road to the Budni Bridge near Garhi Hassan. It carries a very heavy bullock cart traffic, some motor traffic, many animals and many A. T. Carts. The work was done in October 1933, and has been down 14 months.

No maintenance whatsoever has been allowed to be done since the work was finished, so as to see how it would stand.

3. There are six sectors each one marked by a figure painted on an angle iron picket. The first three have a 1½ inch course of gravel underneath to stablise the sub-grade The second three were laid direct on the clay sub-grade, with no stabilising gravel.

4. It will be seen that sectors 1 and 4 are much the best. There is only one pothole in these sectors after 14 months of heavy traffic. These two sectors are marked by red flags at their extremities.

5. The brief specification for these sectors is :—

Lay stabilising course of 1½ inch gravel or else scarify existing gravel sub-grade, Leave surface a little rough so as to get a bond. Spray Bitumuls XRM at ¼ gallon per square yard. Cover with ½ inch layer of gravel, roll and broom-drag. Repeat as necessary according to the traffic to be taken.

6. Actually the thickness now down (not counting original stabilising gravel) on the sectors under inspection is 1½ inch, *i.e.*, three treatments as above.

7. The following general conclusions have been reached as a result of these experiments :—

(*a*) The most rapid and most satisfactory binder is a cold emulsified asphalt. It has advantages over other binders of—

(*i*) Rapidity in laying.

(*ii*) Traffic can use the road during laying.

(*iii*) No necessity for boiler and no heavy plant.

(*b*) A very satisfactory road can be made by using an existing gravel sub-grade, or importing gravel provided that a good bond with the existing sub-grade is made.

(*c*) Where sufficient labour is available near the road mix by hand is preferable to machine mixing.

(*d*) A gang of 200 men can do a mile a day to this specification.

Item 9—Grader Set at Garhi Hassan.

1. The object of the demonstration is to show a grader at work to those who have not yet used these machines. The road being made is a connecting road between the Cantonment and the Chigri Mitti road.

Part of the work is finished and a part easy of access is being done for Members.

2. A grader set, as used here, consists of :—

One 30 H. P. Diesel or Petrol Tractor

One Leaning Wheel Road Grader

One Scarifier

One Revolving Scraper (not actually present)

One Drag Broom.

Other sets can be made up as desired.

The tractor is a 30 H. P. Petrol Caterpillar Tractor.

This set with crew and lorries attached with stores etc. moves along the road as it is built. The machine has built about 100 miles of earth road in Peshawar District.

It does about 20,000 cubic feet of earth per day.

3. The Road Planer, also shown, is a maintenance machine. It is pulled by a light tractor.

This machine works on the Kajuri Plains roads, where it has reduced the annual maintenance estimates for 114 miles of gravel roads from Rs. 76,000 to Rs. 30.000.

4. A road scraper drawn by bullocks is also shown. It is very difficult to get subordinates use this implement properly.

The Auto-Petrol is driven by a 35 H. P. motor mounted on the rear of the frame. The Caterpillar Tractor Coy. now market a Diesel Auto-Petrol.

It is a maintenance machine and has three tools :—

(a) The blade

(b) The scarifier

(c) The multiple blade attachment.

The blade is for grading and finishing and the multiple blade attachment is for smoothing.

The Auto-Petrol on the Chigri Mitti Road has the blade fixed, while the machine with the grader set has the multiple blade attachment fixed.

ITEM 10—PESHAWAR-CHIGRI MITTI ROAD.

1. Members will be shewn about a mile or so of this road, which is a typical example of earth roads constructed with money from the Road Development Fund in Peshawar District. We have completed about 150 miles of road and many bridges on our normal allotment from that fund which is small compared with other provinces. The general principles on which we worked are given in Paper No. 4.

2. The Chigri Mitti road was originally 5 or 6 feet wide and it was usually quite impossible to motor even as far as members are being taken. A few tongas used to work on this road, and their usual method of progress was to unharness the pony and jump him over the ditches. The tonga itself was lifted over, and then the pony was harnessed up again until the next obstacle was reached.

3. The road at present carries 450 vehicles of all sorts per day, whereas before reconstruction it carried only 50. The traffic increase has been so great that an earth surface is now insufficient for it, and the road is being stabilised with gravel.

4. On the return journey the girder bridge over the Budni River is crossed. This is an interesting example of the difficulties of Road Engineers . The bottom of the griders was put 1½ feet about H. F. L. No sooner had the bridge been completed then an exceptional flood came down submerging most of the surrounding country and reaching nearly to the top of the girders. The bridge luckily escaped damage.

Appendix A-II (to the Account of the Congress Tour).

EXPERIMENTAL TRACKWAYS NEAR JARANWALA, PUNJAB.

An interesting experiment of laying a concrete trackway on an unmetalled road has been recently carried out on the Jaranwala-Sayadwala Road (Arterial No. 32) near Jaranwala, in the Lyallpur District. The three specifications followed were those outlined by the Consulting Engineer to the Government of India (Roads). The original intention was to lay an experimental length of one mile of two tracks two feet wide spaced 2½ feet apart so that they were the same distances, centre to centre, as the wheels of an ordinary bullock cart. An estimate amounting to Rs. 10,044 was accordingly framed but for the time being only half a mile has been laid.

The primary object of this trackway is to make an unmetalled road, which carried normal traffic, and contains ordinary good Punjab alluvial soil and capable of standing upto normal traffic, more suitable for bullock carts; and the idea underlying the whole experiment is that this trackway will be mainly used by loaded bullock carts,

while motor and other vehicles can travel on to the earth road without inconvenience. The trackway has been laid in accordance with the three specifications detailed below :—

Specification No. I.—[See section at figure (1) sheet No. 1] : Length laid 1,320 feet in furlongs 1 and 2

Bottom course.—Width 2 feet 3 inches, thickness 9 inches. Lime concrete with well burnt brick ballast and 33 per cent., 3 to 2 Surkhi and lime mortar. The brick ballast was broken from well burnt bricks.

Top course.—With 2 feet, thickness 3 inches. Portland cement concrete, 90 lbs. cement : 2 cubic feet local sand and 4 cft. Pathankot bajri, gauge 3/8 to 3/4 inch. This was laid in lengths of 25 feet with 3/8 inch expansion joints. These joints were filled with a mastic composed of equal parts of Mexphalte and cement and 5 parts sand.

Under each joint, at the time of construction, cement concrete was laid in place of lime concrete *vide* longitudinal section.

Specification No. II.—Length 660 feet laid in furlong 3.

Bottom course.—Same as for specification No. I except that the thickness is 4½ inches.

Top course.—Same as for specification No. 1.

Specification No. III.—Length laid 660 feet in furlong 4.

Top course.—Same as for specification No. 1.

Bottom course.—As in specification No. I.

Top course.—As in specification No. I except that a channel 1 foot 9 inches wide and 1 inch deep was counter sunk in the cement concrete slab which was later filled with a 1 inch carpet of Premix. Five and a half chains of 1 inch carpet was laid with Premix composed of Pathankote bajri graded from 1/8 to ¾ inch and coated with 5 per cent. of a mixture of equal parts of Mexphalte and Shelmac. To insure good mixing the bajri was also heated. The Mexphalte was heated to 350°F. while the Shelmac was heated to 250°F.

In one chain instead of bitumen five per cent of Road Tar No. 2 was used. In a short length the surface of the concrete was painted at the rate of .12 cwt. per 100 sft. with Road Tar No 2 and the Mexphalte Premix laid over it. The object being to provide a better bond between the concrete and the carpet.

Construction.—This work was put in hand at the end of August and completed on the 9th November and the road was opened to traffic on the 12th. As the original level of the road surface was lower than ground level, the road surface was raised about 1½ feet in the centre and the entire road width of 44 feet between drains was dressed to a continuous camber. This earth work was laid in 6 inch layers and each layer was watered and rolled with a one ton concrete bullock roller. When the road formation gave every indication of being well consolidated trenches were dug for the trackway and the bottom of the trenches were again well watered and rammed. Lime concrete was then laid according to P. W. D. Specifications in these trenches in layers not exceeding 4½ inches with all joints broken and it was well consolidated with hand rammers. When the lime concrete set the cement concrete wearing coat was laid. The cement concrete was kept wet for about 10 to 12 days after which it was allowed to dry and the expansion joints were filled with mastic and in the last furlong the channel in the concrete was filled with a 1 inch carpet of Premix. A hand roller was used for consolidating the Premix.

The actual cost of each type of trackway is given on sheet No. 2 below and from these figures the cost per mile has been deduced for each specification.

It is too early to make any reliable comments as to whether this type of trackway will solve the problem of making unmetalled roads suitable for carts in all weathers. It is, however, clear that in order to preserve the trackway it will be essential to continually make up the earthwork between the tracks and on each side, so as to protect the edges and the maintenance of this may be so costly as to make this type of trackway impracticable. For the purpose of comparison the cost of different types of metalled road, 12′ and 9′ have been taken out and it appears that a trackway to any of the above specifications is more expensive than a 9′ wide metalled water-bound road, surface treated with two coats of tar. The justification for trackways must lie in low maintenance costs.

SHEET No. 2.

Comparative Statement of costs of Trackway laid on Arterial Road No. 32, unmetalled, near Jaranwala in the Lyallpur District.

Serial No.	Items of works.	Rate.	Specification No. 1 (Length 1100).		Specification No. 2 (Length [illegible])		Specification No. 3 (Length 660)	
			Quantity.	Amount.	Quantity.	Amount.	Quantity.	Amount
			Cft.		Cft.		Cft	
1	Earthwork for road embankment.	4 0 0	79,200	317	59,[illegible]	[illegible]	39,600	158
2	Excavation in foundations .	4 0 0	6,215	25	1,665	7	2,970	11
3	Lime concrete . . .	23 8 0	4,685	1,101	1,050	[illegible]	2,127	500
4	Cement concrete work .	92 0 0	1,595	[illegible]	726	[illegible]	568	523
5	Premix 1" thick . . .	1 Cft.	...	.	...	...	193	193
6	Supervision work charged establishment.	...	Job	60	Job	30	Job	55
	Total .	...	...	[illegible]	...	1,111		1,420
	D-D Contractor's Abatement	11 8 0	..	[illegible]	.	[illegible]61	..	208
	Total .	...	..	2,[illegible]		970	..	4,121
1	Cost of trackway specification No. 1 for one mile.		P. Mile 9,200					
2.	Cost of trackway specification No. 2 for one mile.				P. Mile 7,600			
3	Cost of trackway specification No. 3 for one mile.						P. Mile 9,713	

GIPD—537ConEngDofI&L—29-7-35—750.